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DOVE MARINE LABORATORY,

CULLERCOATS, NORTHUMBERLAND.

REPORT

For the year ending June, 1915.

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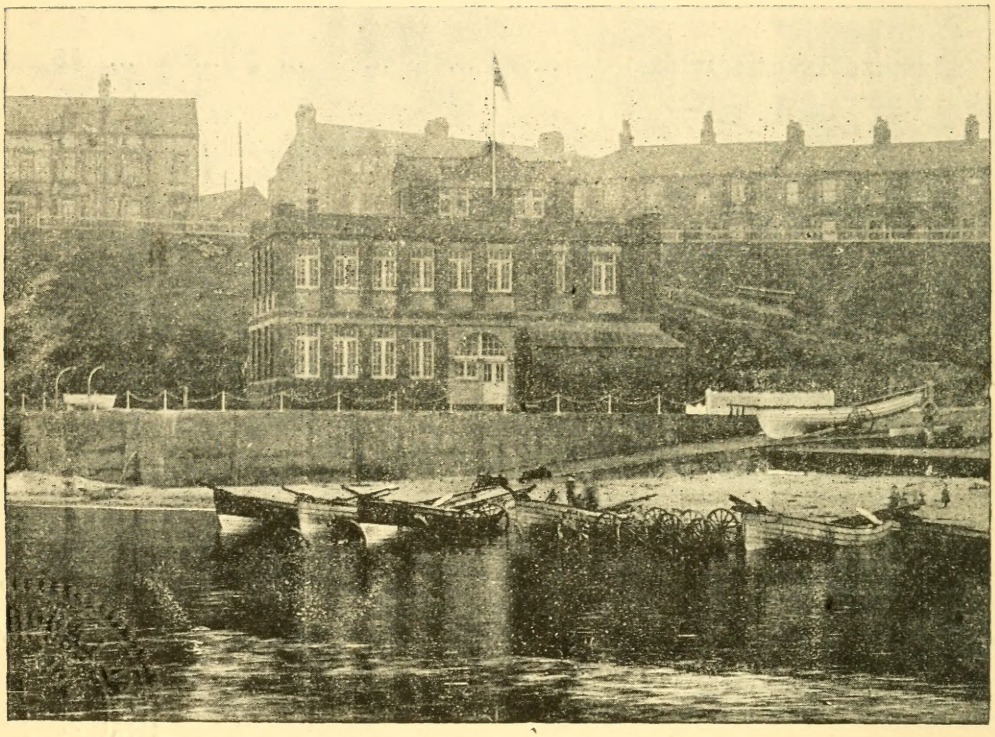

DOVE MARINE LABORATORY, CULLERCOATS.

SUMMARY AND GENERAL REPORT.

The work of the Laboratory during the past year has naturally been restricted, but the members of the staff, in addition to identifying themselves with military activities in the district, have been useful to the Board and the inshore fishermen in connexion with regulations relating to fisheries, and the question of possible distress. The Laboratory's motor boat "Evadne" has since the end of last summer been lent to the Admiralty. The Report therefore deals for the most part with work done in the Laboratory.

This Report, like the last, is concerned to a large extent in a consideration of the principles underlying the migration of fish. In the paper on the migrations of the gurnard, it is shown that the young are gathered in a region which may be called the recruiting ground, and that up to the time of maturity they migrate inshore in summer and offshore in winter. After the denatant (see note page 14) drift of the egg and larvæ the recruits of the Northumberland school of gurnards migrate inshore, and still denatantly. This is followed at the end of the second summer by an offshore and contranatant migration. Thereafter, with growth, the contranatant winter migration becomes more and more marked, the larger immature gurnards moving further to the north and into deeper water, the result being a segregation according to size and depth. When mature the gurnard migrates still further in the contranatant direction, and it is more than probable joins the spawning migrants of a school of another region, if not at the first, at a subsequent

season of ripening. The gurnard thus has a life history similar to that of the northern migrants described in the last report.

A few further interesting recaptures of marked dabs, lobsters and a crab are reported, which add to our knowledge of the migration of the mature in these species.

The paper by Mr. Storrow on the investigations relating to the herrings, deals with part of the work done at the Laboratory last year. A synopsis is given of the particulars relating to size, age and maturity of the samples, which totalled about 3,200 herrings. The Dogger Bank herrings on this occasion could not be investigated, as the region was closed to fishing, and this was the more regrettable as in the previous years we had found that the homogeneity of the school was evidenced by the dominance of successive year groups amongst the immature. The herrings of the Northumberland and Yorkshire coastal waters were subjected however to a careful analysis, according to the method agreed upon. Attention is drawn to the difference in age-composition between the Northumberland and Yorkshire trawled herrings, and to the fact that year after year the Northumberland herring present a large percentage with three winter rings.

Mr. Herbert Paul has contributed an account of his work on the autotomy of the limbs in Decapod Crustacea. He has described the result of his investigations leading to interesting conclusions as to the structural and physiological features which bring about the weakening at the breaking plane; and the difference as to the motive between Macrura and Brachyura.

Mr. T. Bentham has described in a short note a Hæmogregarina which he found in a small example of the common skate, *Raia batis.*

A remarkable case of "parental" care in the Genus Cottus was observed in a tank in April this year, and a note with regard to it is given. The group of eggs was laid by a *Cottus scorpius* and the guardianship was assumed by an immature female *Cottus bubalis.*

Pilchards evidently annually migrate into the North Sea in summer, and are caught in herring nets. Mr. Storrow has examined a small sample of these spent fish, and gives interesting particulars as to age-composition and growth.

Attention is drawn to the records given under the title "Faunistic Notes."

So large a number of eggs of plaice, flounder, cod and whiting appeared in the tanks during the last few years that it was thought worth while to place them in the sea off Cullercoats. It was estimated that this spring the numbers liberated were plaice 337,000, cod 203,000, whiting 65,000.

ALEXANDER MEEK.

30TH JUNE, 1915.

THE MIGRATIONS OF THE GREY GURNARD, *Trigla gurnardus.*

By ALEXANDER MEEK.

The earlier Northumberland trawling experiments indicated that gurnards migrated into the bays along the coast in summer, and that they were more numerous in the southern bays than in the northern. The later experiments allow of the facts regarding their distribution being better expressed in figures (Table I.).

The annual invasion of the Northumberland inshore waters, it will be seen, is subject to a good deal of variation. There are good seasons in which all the bays participate, and bad seasons which also affect the whole of the region. But a glance over the figures plainly indicates that the two middle bays, Alnmouth and Druridge, which are only about three miles apart, receive usually the greatest numbers, and in years of plenty as 1900, 1902, 1909 and 1913 this feature is particularly well exemplified. On the average, it may be said that these mid-Northumberland bays afford about 50 gurnards per hour's trawling in the summer. The southern stations which are also close together yield about 16 gurnards, and the northern ones about three (fig. 1).

From the report for the year 1908 (Table IV., page 21) it will be evident that the gurnards arrive in Alnmouth Bay in April, and in Druridge and Blyth Bays in May, and leave the inshore regions about October or November. The immigration becomes most intense, however, in June and July, reaching a maximum in July and August at Alnmouth, and in August in the southern parts of the district.

A consideration of the results of the trawling experiments made in 1913 (see Report, new series, III., 1914, Table III, page 23) will be found to illustrate with reference to one season the features of the migration which have been found to be practically constant for a large number of years. The results are expressed in figure 2. At Alnmouth the catches from May to September

averaged 360 per hour, the catch of November 1st, 4 ; at Druridge the summer catches for the same period averaged 49, the November, 3. Figure 2 conveys the impression that the wave of gurnards reaches Alnmouth first and passes onwards to Blyth, that the spring or early summer maximum of Druridge expands into the single maximum of Blyth, and that Druridge again expresses by a second maximum the return of the gurnards to the north. It is tolerably certain that in 1913, in August, Druridge suffered a temporary relapse in the number of gurnards for it was visited twice during the month, and on both occasions the same feature was experienced. It is probable therefore that when the gurnards arrive in shallow water they continue for a period to move southwards along the coast. This would serve to explain the double maximum in Alnmouth Bay, and this it must be said has been noted to be general. But it is not necessary to conclude therefrom that the gurnards of Druridge migrate to Blyth, but rather that the maxima express the general movement to the south when the fish reach the coast, and that Blyth lies near the distal end of the school.

The details of measurements are given in the same Report (Table II., pages 12 to 22), and those referring to Alnmouth Bay are represented in the form of a diagram in figure 3. The curves indicate with reference to size the catch per hour each month. It is not necessary to point out that there is an increase culminating in August, and that already in September the greater part of the fish had already left. The figures for August were so great as to render it necessary to show the curve in a broken manner as will be readily evident.

This presentation of the conditions in Alnmouth Bay for 1913 makes it clear that the migration concerns mainly the young, immature gurnards. Of these also it is evident that the smaller appear first, and that the size gradually increases during the season. The small number of older and mature fish appear late. It is also clear that they depart in the same order. The conclusion is warranted then that the young small fish come from a region near at hand, while the larger ones migrate from distances which increase with size. It has been natural to assume from such a presentation of results of experiments that the change in the maximum from 16 cm. in June and July to 18 cm. in August indicates growth. But it is not in the light of the facts of the migra-

tion at all unlikely that the increase in size is due to a segregation even of the fish of a given year according to size and depth.

The following notes will render the picture clear with reference to the other bays. In May, the gurnards at Druridge were larger than at Alnmouth, and at Blyth the few gurnards were all large. In June and July the conditions were practically unchanged. In August, the few gurnards at Druridge were medium and large, and the young gurnards had arrived at Blyth. In September, Druridge received a further accession of medium and large, and only two small were captured at Blyth.

The school of gurnards, the summer conditions of which have been described, may be called the Northumberland school. The next school to the north is one which may be styled the Forth school. The trawling investigations made with the "Garland," and the later investigations made with the "Goldseeker" serve to indicate that the summer inshore migration is practically the same as that of the Northumberland. The following figures give the "Garland" results for the years 1888-1893, and the "Goldseeker" results for the period 1903-1909.*

	"Garland."	"Goldseeker."
St. Andrew's Bay	59 ...	...
Forth Station 6	37 ...	13·7
,, 2	28 ...	11·2
,, 4	35 ...	4·2
,, 7	21 ...	9·2

The region to the south of the Forth, including the northern half of Northumberland, may be regarded as the southern distal part of this school. Only small numbers of young gurnards reach this part, the majority of the gurnards being large mature spent fish which enter the region after spawning.

There is a slight degree of evidence (from a visit to Blackhall Bay, Hartlepool, in August, 1897, when the gurnard catch per hour was found to be 33) that another school visits the southern Durham and northern Yorkshire coast.

These schools therefore only occur inshore in the summer from about May to September or October. But there are early and late seasons. Not only so, the figures in Table I. serve to show that the school may occupy a more southerly position in some seasons as in 1904-1908, due evidently to seasonal variations in the drift of the fry.

* See also Fulton, 17th and 21st Ann. Reps. Fish. Bd. for Scot. (1899, 1906).

Manifestly when the gurnards leave the inshore waters they migrate out to sea, and judging from the results with relation to the migrations of the plaice (report for last year, new series, III., 1914) it may be presumed that the outward migration is to the north. The local trawlers obtain small gurnards in small quantities off the coast of Northumberland, but they increase in numbers to the north, and reach a maximum in numbers and in size to the north-east of the Longstone. In this region the gurnards are most plentiful from November to May. This it would not be easy to give in figures without a considerable degree of trouble. It would mean analysing the North Shields records of the local catches made by trawlers, but it indicates in words the experience of the trawlers.

It may be said therefore that the Northumberland school of gurnards winters offshore opposite the northern part of the county and that the members are spread over a wide area, the small gurnards in shallow water and to the south, and the larger gurnards in deeper water and more to the north. It is not to be supposed that they migrate to a particular spot and stay there, but this is the average result of a general movement. In the spring, the school migrates as a whole southwards and towards the coast, the small arriving first and the larger later as the foregoing investigations have shown. It may further be concluded that the inshore migration results in a concentration of the members of the school, and that during the winter migration the segregation becomes more manifest (fig. 4).

The other schools on the east coast will probably be found to be related similarly to winter grounds situated to the north-east of the summer feeding area.

The explanation of the origin of the schools must obviously be sought in the fact that the fish assemble in certain areas for spawning. The spawning season of the gurnard is April to August. The egg is a pelagic one, measuring 1·2 to 1·5 mm. in diameter, and hatching takes place after from a week's to a fortnight's oscillation in the tidal currents, resulting, however, in a drift to the south in the regions now under consideration. The larva on emergence measures about 3·5 mm. and is pelagic also. The drift is continued while the larva is growing, but the young gurnard gradually sinks in the water and finally after a period which cannot

be definitely stated it reaches the bottom. It may be said then to be about 1 cm. in length. During its pelagic life the young gurnard develops large pectoral fins which will enable it to some extent to resist the current. But the conditions are such as to cause a gathering on the bottom over a wide area, and varying in depth, say, from about 5 to 30 fathoms of the products of a particular spawning ground (fig. 5). If we had the means to examine such an area in the latter part of the year we should expect to get a picture of the population of the young gurnards of the year which would be very similar to that expressed in fig. 1 of this paper.

These young gurnards would also be found to vary in size because of the long spawning period, and probably they do not move far if at all during the first winter. But in spring they migrate inshore, and measure from 7 to 12 cm. (one year). At the end of the summer they retreat into somewhat deeper water without as a rule quitting the territorial region, and re-enter the bays along the coast a second time when they measure 13 to 20 cm. (two years). The succeeding winter migration carries them still further north and into deeper water, and on their return to the shore they have attained a size of from 18 to 24 cm. (three years). It is very probable that at the end of this season inshore the majority of the males and some of the females become mature, and the result will be to intensify the distance of the winter migration, from which they will return to a spawning ground; and from what we know with regard to other species it may be said this need not be the one from which they originated, but one still further to the north (fig. 6).

The life-history of the gurnard may be concluded therefore to be :—

1.—A denatant drift of a number of weeks in the egg and larval stages, a gradual sinking in the water, and the coming to rest in depths of from 5-30 fathoms, but for the most part in 10-25 fathoms.

2.—Next spring a denatant migration inshore, and a concentration of the products of the previous year's spawning season.

3.—A contranatant migration into deeper water again at the end of the summer.

4.—Thereafter a seasonal migration from deep water to shallow water, and as in the previous cases the spring migration being from

the north and the autumn migration to the north (east coast of Britain, north of the Wash). With increase in size the outward migration is still further to the north and into deeper water.

5.—Coming maturity impels the fish to migrate in winter contranatantly to a still greater distance from which it will return with the spawning migrants. It is probable if not on the first occasion at some succeeding season the outward migration may be such as to associate the fish with spawners of a region related to another school. So far as is known this is usually if not always in the contranatant direction.

6.—After spawning the spent fish join the summer denatant migrants and migrate later than these and evidently further than these for winter.

If the contention be admitted that the schools owe their origin—and there does not appear to be any other explanation—to the showering of the young on the ground in a region which must bear an average relationship to the spawning ground on the one hand and to the summer feeding ground on the other, it follows that if we knew the factors, the history in this and similar cases could be completely stated. We do not yet know the spawning ground of each of the schools, the normal period of pelagic life, the region where the demersal fry are mainly congregated in each case, and the mean rate of the current during the spawning season in different regions.

Note.—In this and the following papers dealing with migrations, two words with their variants are introduced to express migrations with reference to current. They were suggested by my colleague, Professor J. Wight Duff. *Denatant* is applied to migrations with the current, and *contranatant* to migrations against the current.

In the sea particularly the eggs and the larvæ or the larvæ alone are rotated by the tidal currents, and at the same time carried passively in a definite direction by the oceanic current. The path may be represented by a spiral beginning over the spawning ground and ending at the recruiting ground. This passive denatant drift is succeeded by the seasonal and the spawning contranatant and denatant migrations. The use of the terms will be clear from the above paper and figures 4—6.*

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* 1915, Meek, " Nature," p. 231 (April 29th).

FIG. I.—The Average Catch per Hour of Gurnards by the Experimental Trawl Net at the Northumberland Stations.

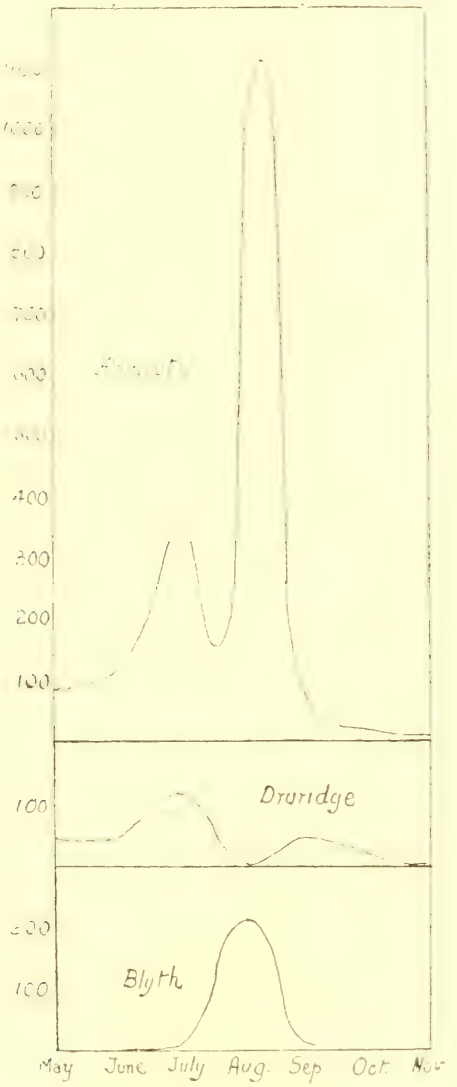

FIG. II.—The Catches of Gurnards in 1913 at the Stations Named.

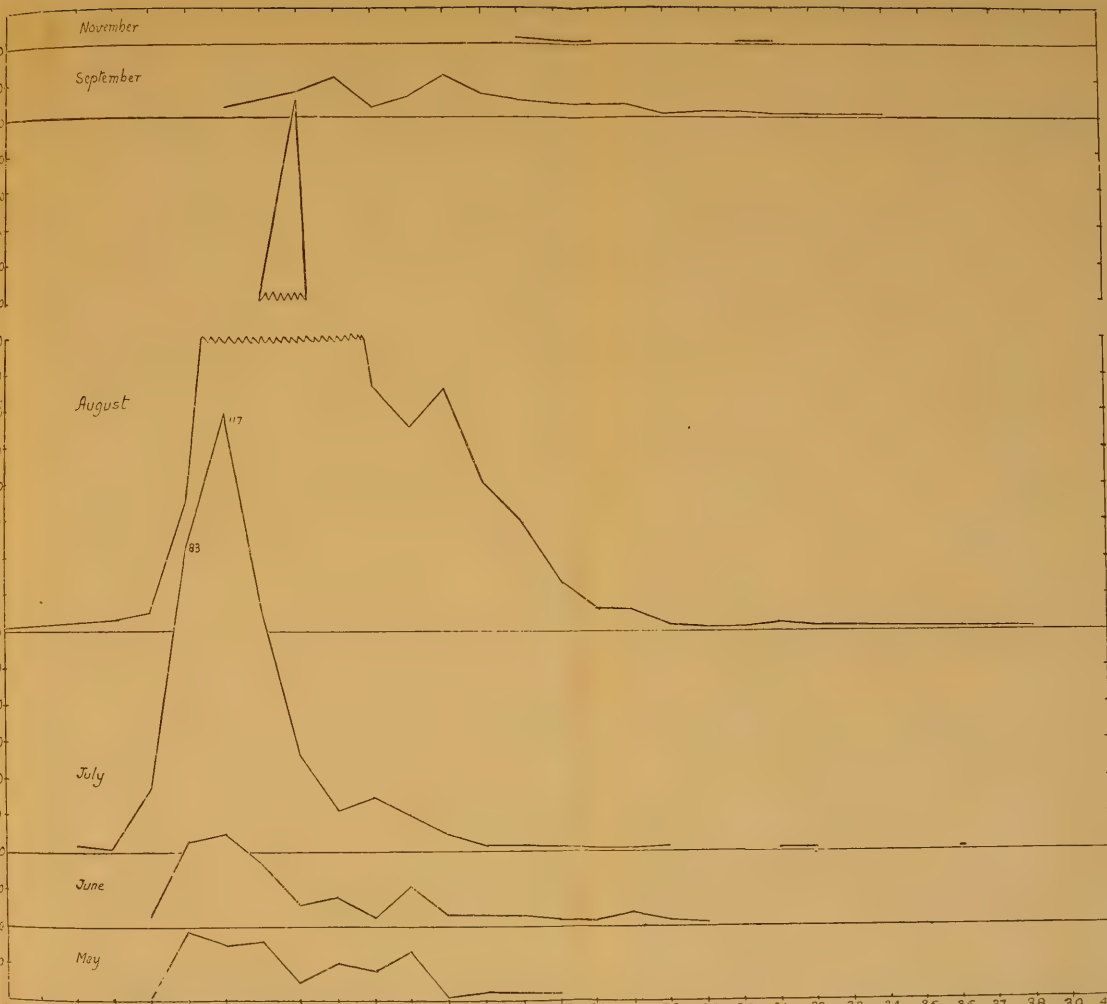

FIG. III.—The Catches of Gurnards at Alnmouth Bay in 1913 in Successive Months.

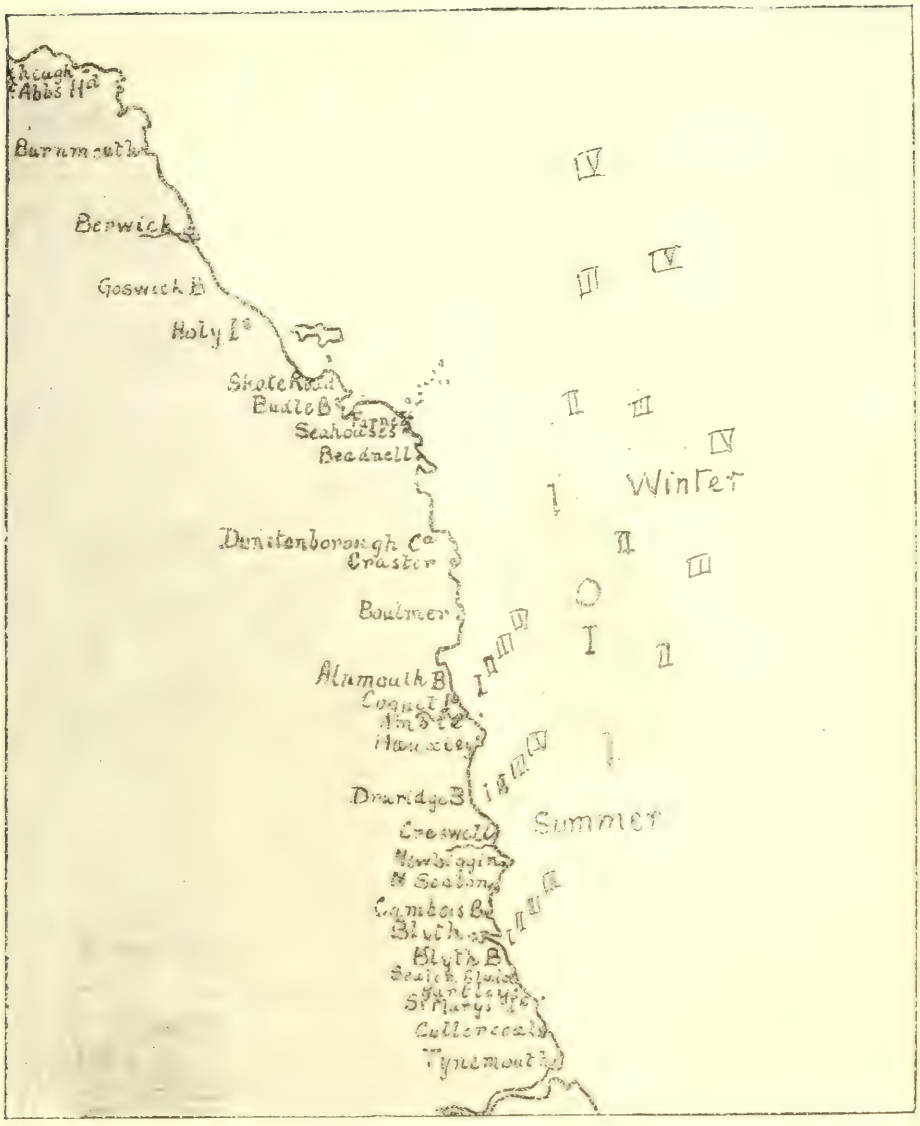

FIG. IV.—The Migration of the Grey Gurnard.

O = Recruiting ground of school, and I.-IV. the positions of the migrants as a result of the annual summer denatant and winter contranatant migrations.

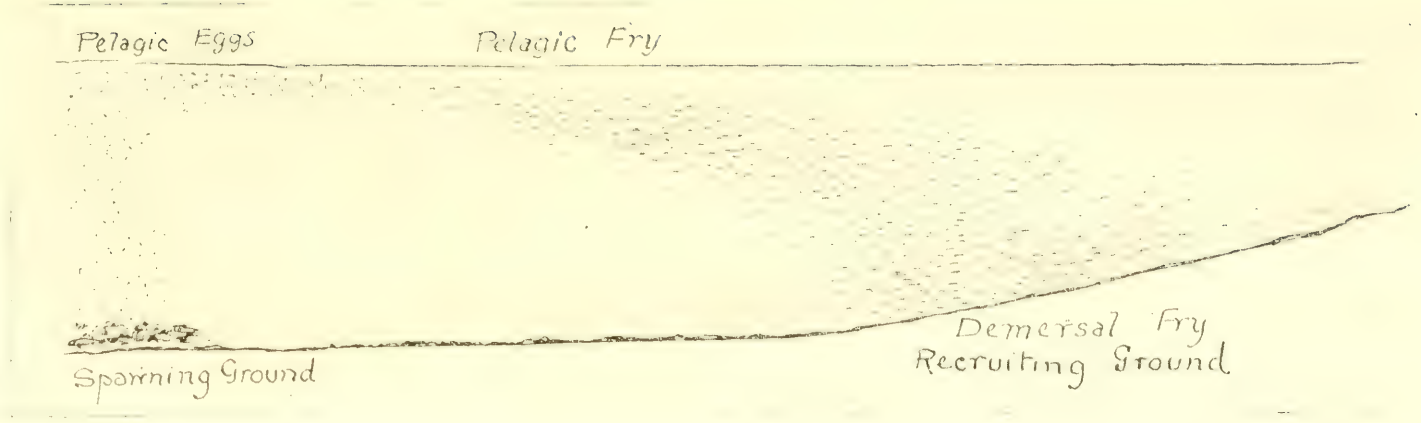

FIG. V.—The Migrations of the Grey Gurnard. The Denatant Drift of the Eggs and Young.

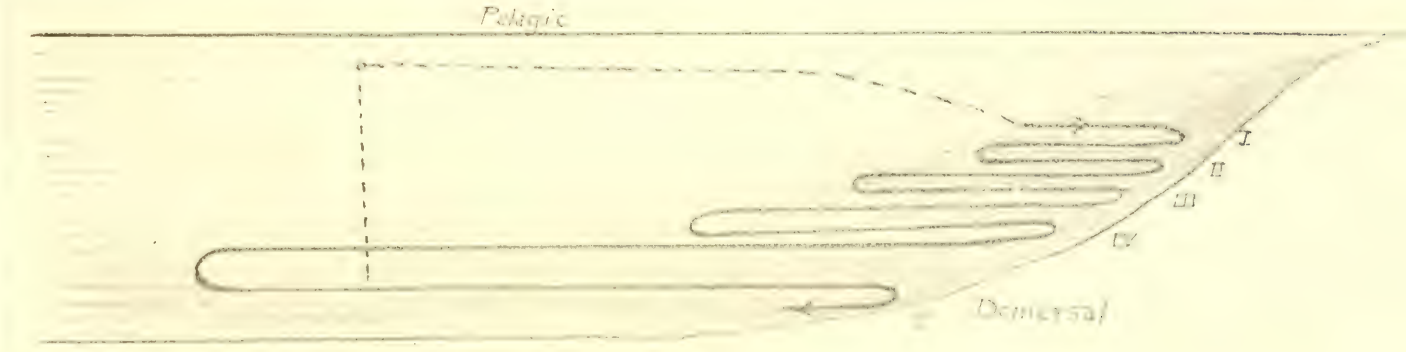

FIG. VI.—Diagrammatic Representation of the Migrations of the Grey Gurnard.

TABLE I.—GURNARD.

Catch per One Hour's Trawling.

	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.	Mean.
Goswick	—	—	2	—	1	—	—	—	—	—	—	—	—	—	—	1
Skate Roads ...	1	3	3	7	2	—	2	10	2	8	1	—	—	—	16	5
Alnmouth ...	7	78	2	140	36	1	14	30	13	33	118	17	—	—	360	65
Druridge ...	10	35	5	55	33	11	22	49	76	41	30	36	—	—	49	35
Cambois	16	29	11	21	12	10	11	—	—	—	—	—	—	—	—	16
Blyth	—	15	5	2	13	11	11	24	12	13	10	11	—	—	74	17
Mean ...	7	32	5	45	19	7	12	28	26	24	40	21	—	—	125	—

HERRING INVESTIGATIONS.

Size, Age and Maturity.

By B. STORROW.

During 1914, samples of herrings landed at North Shields have been examined at the Laboratory at the request of the Board of Agriculture and Fisheries. The data obtained have been forwarded to the Board, but it was thought desirable to make some statement with regard to size, age and maturity to allow of comparison being made between these fish and those examined during 1913.

As in 1913, ordinary commercial samples were obtained for the drift net herring and also for sample 10, as the catch from which it was taken was not sorted before being placed on the market. In taking the samples of trawled herring, samples 12 and 13, the quantity of each trade category, large, medium and small, was first ascertained, and the samples taken to include various proportions of each class.

Altogether, thirteen samples, comprising some 3,200 herrings, have been examined.

The first of the samples was taken during the period when the herring drifters were line fishing, the herrings then being caught for bait, and the surplus marketed when the line fish were landed. Although the fishermen assured me that the herrings had been taken indiscriminately for bait, it must not be forgotten when dealing with this sample, that the tendency would be for the fishermen to use the small for bait in order to obtain a higher price for the remainder; there is therefore a possibility that the sample is not representative of the shoal fished as regards age composition and size.

Sample 2 was examined to obtain some knowledge of the small fish which are usually caught at the beginning of the herring season.

The fish landed during the summer herring fishing, from June to August, and captured by drift nets, are represented by samples 3 to 9.

In August, owing to the war, many of the trawlers were obliged to fish over ground in the vicinity of the herring boats, and quantities of trawled herrings were occasionally landed. These, although caught by the trawl, as will be seen from a consideration of the age composition of sample 10 are, without doubt, the ordinary summer herring of the Northumberland coast.

Herrings from a more southerly ground than is usually fished from North Shields are to be found in sample 11.

The trawled herrings which were landed at North Shields during the autumn of 1914 were obtained off the Yorkshire coast, and two samples of these, 12 and 13, were examined.

The samples examined were as follows :—

Sample.	No.	Date.	Where Captured.	Net.
1	467	30th April ...	100 miles E. of Tyne	Drift
2	172	19th May ...	18½ miles S.E. by E. of Tyne	Drift
3	250	8th June ...	15 miles E.N.E. of Tyne	Drift
4	250	22nd June ...	22 miles E.S.E. of Tyne	Drift
5	250	6th July ...	30 miles E.S.E. of Tyne	Drift
6	250	13th July ...	28 miles E.S.E. of Tyne	Drift
7	250	20th July ...	20 miles E. by S. of Tyne	Drift
8	250	27th July ...	20 miles N.E. by E.¼E. of Tyne	Drift
9	250	5th August ...	23 miles E.N.E. of Tyne	Drift
10	250	24th August ...	23 miles N.E. of Tyne...	Trawl
11	205	8th September	30 miles S.E. by E. of Hartlepool	Drift
12	200	30th September	70 miles E.S.E. southerly of Tyne	Trawl
13	200	12th October ...	75 miles S.E. by E.¼E. of Tyne	Trawl

Size.—Particulars relating to the size of the herrings examined will be found in Table I. As in 1913, the fish have been grouped to the nearest centimetre, 20·6 to 21·5 cm. being counted as 21cm., and the numbers obtained expressed in percentages.*

In 1913, the length was measured from the snout to the middle of the fork of the tail when in its natural position, whilst in 1914 the upper lobe of the tail was moved so that its upper edge was parallel to the mid line of the body ; this gave a difference in favour of the 1914 measurements of from 2 to 3 mm. in herrings from 22 to 25 cm. in length.

The first sample consisted of fairly large fish, the majority being from 25 to 26 cm. and more in length.

Sample 2 has been referred to already as a sample of small herrings, and as will be seen from the table, was composed mainly of fish from 21 to 23 cm. long.

* Report, 1914, New Series, III., page 60, line 3, *for* 20·5 to 21·4 cm. *read* 20·6 to 21·5 cm.

The herrings taken off the Northumberland coast from June to August varied in size from 19 to 30 cm., the greater part of them being fish from 23 to 25 cm. long, and differing little from those of 1913. In August, the samples contained slightly smaller fish than those of the previous year, but it will be seen later that this may be due in some part to the locality where the samples were captured.

Sample 11 consisted of fairly large herrings, the highest numbers obtaining from 25 to 27 cm.

The trawl caught herrings were larger than those from the Northumberland coast, and as in 1913 the greater part of them were from 24 to 28 cm. in length. In this respect they agree somewhat with sample 11, but a consideration of the age composition of the samples will show that they belong to a different shoal.

Age.—For the purpose of comparison as to age composition, the samples can be grouped according to the regions where captured, which are 100 miles east of the Tyne, the Northumberland coast, the Yorkshire coast off Whitby (sample 11), and the Yorkshire coast trawled herring ground. The difference between the age composition of the samples from these regions and where possible a comparison with herrings obtained from the same grounds in 1913 are shown graphically in Chart II., and Table II. gives the numbers and percentages of herrings having different numbers of winter rings in each sample.

The first sample differs from the others in being composed of older herrings, the predominant year groups being those with four and five winter rings, whilst there is a fairly high percentage, 17, of fish with six winter rings. The scales showed that the summer growth had commenced only a short time previous to the capture of the fish, and in some of the older individuals the edge of the scale and the last winter ring practically coincided. This was the case in all with eight or nine winter rings, in 75 per cent. of those with seven, and 15 per cent. of those with six winter rings.

Sample 2, caught 19th May, had for its predominant year groups fish with two and three winter rings ; there was only 7·7 per cent. of the catch not included in these two year groups.

Samples 3 to 9 inclusive, taken from the 8th of June to the 5th of August, and representing the ordinary summer herring of

the Northumberland coast, consisted chiefly of herrings with three winter rings, as was the case in 1913. The age composition of the samples taken in 1913 and 1914 during the same months was as follows :—

WINTER RINGS.

Samples.	1	2	3	4	5	6	7	8	9	10
1913—A-G	...	13·2	47·2	30·8	8·6	0·1	0·1	...	...	...
1914—3-9 ...	0·2	24·5	53·7	14·6	4·8	1·5	0·5	0·2	0·1	0·1

It will be noticed that there is some variation for fish with two and four winter rings, and also that the percentage of herrings with more than five winter rings is again very small. It would appear then that during 1913 and 1914 the local herring grounds have been more of a nursery for developing fish than a spawning ground for the mature.

Hjort has recorded for the Northumberland coast for 1911 a predominance of herrings with three winter rings,* and this we have found to characterise them in the years 1912-14.

Younger fish are no doubt to be found nearer the coast, but any quantity of these, owing to the selective nature of the drift net, has not yet been obtained.

Sample 10, although caught by the trawl, differs little from samples 3 to 9 as regards age composition. It is without doubt a sample of the same class of fish, and has therefore been included when drawing the curve on Chart II.

The herrings from 30 miles S.E. by E. from Hartlepool, and as will be seen from Chart I. caught nearer the shore than samples 3 to 10, are of interest as being on the whole older than those from the Northumberland coast. Although the predominant year class had three winter rings, the number of fish with two winter rings was smaller than in any of the Northumberland samples, and comprised only 4·5 per cent. of the sample. Of fish with four and five winter rings there were 24·0 and 14·5 per cent. respectively.

The two samples of trawled herrings from the Yorkshire coast ground had an average age composition as follows :—

WINTER RINGS.

1	2	3	4	5	6	7	8	9	10	11	12	13
1·0	8·5	24·8	16·0	28·8	10·5	4·0	2·3	1·3	1·0	0·3	0·3	0·8

* Rapports et Procès-Verbaux des Réunions, vol. xx., page 69.

In 1913, the predominant year class for these herrings had four winter rings. There is no doubt then that we are dealing here with an altogether different shoal of fish from the drift net herring of the Northumberland coast. Had they belonged to the same shoal and been recruited from the Northumberland coast herring as these approached maturity, there should have been in 1914 not only a high percentage of fish with five winter rings, but also a still higher percentage with four winter rings, seeing that in 1913 almost 50 per cent. of the Northumberland coast herring had then three winter rings.

The question then arises as to what becomes of the Northumberland coast herring on approaching maturity. There is at present little evidence to throw any light on this point, but the following suggestion is put forward.

It will be noticed that the fish of sample 11, captured further to the south than those of samples 3 to 10, were on the whole older than those from our local waters. In 1909, Hjort had samples of herrings taken at Grimsby and Lowestoft, and the age composition of these was as follows :—*

	WINTER RINGS.										
	2	3	4	5	6	7	8	9	10	11	12
Grimsby—											
30/9/1909 ...	3·3	29·2	42·7	13·9	5·2	1·9	1·2	1·9	0·6	...	...
Lowestoft—											
9/11/1909 ...	1·5	7·6	25·1	26·6	13·8	9·9	10·2	2·5	1·7	0·7	0·2

Lowestoft is further to the south than Grimsby, and is in the vicinity of what must be regarded with our present knowledge as the chief spawning ground of the southern North Sea herring.

It is evident that the young herrings during larval and post-larval stages are carried some considerable distance from the spawning ground, and pass their first year in relatively shallow waters. In the next year they partake of a summer migration still in a denatant direction. The summer migration has a corresponding winter contranatant migration. These migrations continue yearly, the fish migrating into deeper water each winter, and returning towards the coast each summer until the call of maturity comes, when they join the spawning migrants, probably the summer after the fourth or fifth winter ring has been formed.

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* Publications de Circonstance, No. 53, pp. 144 and 151.

Further evidence is necessary and would probably be obtained by taking samples of herrings at different localities along the coast between Northumberland and Lowestoft. If these samples were taken during the height of the herring season at the various ports, they would admit of comparison being made for this purpose.

A somewhat similar distribution for the young, and migration towards the spawning ground on approaching maturity have been shown by Hjort and Lea from a consideration of the 1904 year class, marked herrings, of Norway.

Size and Age.—Particulars relating to size and age will be found in Table III., and for the purpose of comparison the herrings examined during 1913 have been similarly arranged and classified in Table IIIa.

The average sizes, as calculated from the table, of the different year groups in the samples of the Northumberland coast herring are as follows :—

WINTER RINGS.

Sample.	2	3	4	Month.
2	21·3	22·5	24·1	May.
3	22·7	23·9	25·7	June.
4	22·1	23·3	25·3	June.
5	21·8	23·4	25·1	July.
6	22·9	24·0	25·5	July.
7	22·3	23·5	25·4	July.
8	23·6	24·4	25·8	July.
9	22·7	24·1	25·4	August.
10	22·3	23·8	25·5	August.

The samples examined in 1913 which admit of comparison had the following average sizes :—

WINTER RINGS.

Sample.	2	3	4	Month.
A	22·0	23·2	24·1	June.
B	22·1	23·2	24·0	June.
C	22·1	23·0	24·5	July.
D	21·9	23·6	24·5	July.
E	23·4	24·2	24·9	August.
F	23·2	24·9	25·4	August.
G	23·7	24·3	25·2	August.

Taking into consideration the difference between the two methods of determining the total length, there is little difference between the size of the herrings with two and three winter rings, but those with four winter rings were larger in June and July than the fish of similar age in 1913.

The herrings of 1913 showed some increase in size during the three months under consideration, but apparently the same cannot be said for those in the samples of 1914.

In last year's Report, page 63, it was shown that during the first and second weeks in September a change took place in the local herring shoals, there being an immigration of fish with two and three winter rings having a smaller growth increase for 1913 than those previously forming the shoals. These immigrants were spoken of as being probably later migrants into the North Sea, but it is very doubtful if young fish of this age partake of such an extensive migration. Similar changes in the composition of our local shoals may have taken place in 1914, and may account for the apparent lack of growth. In 1913, the June, July and first August samples were taken further to the north than the others, and it is probable that the same shoal may have been followed south by the fishermen, thus bringing about the gradual increase in growth as shown by the samples.

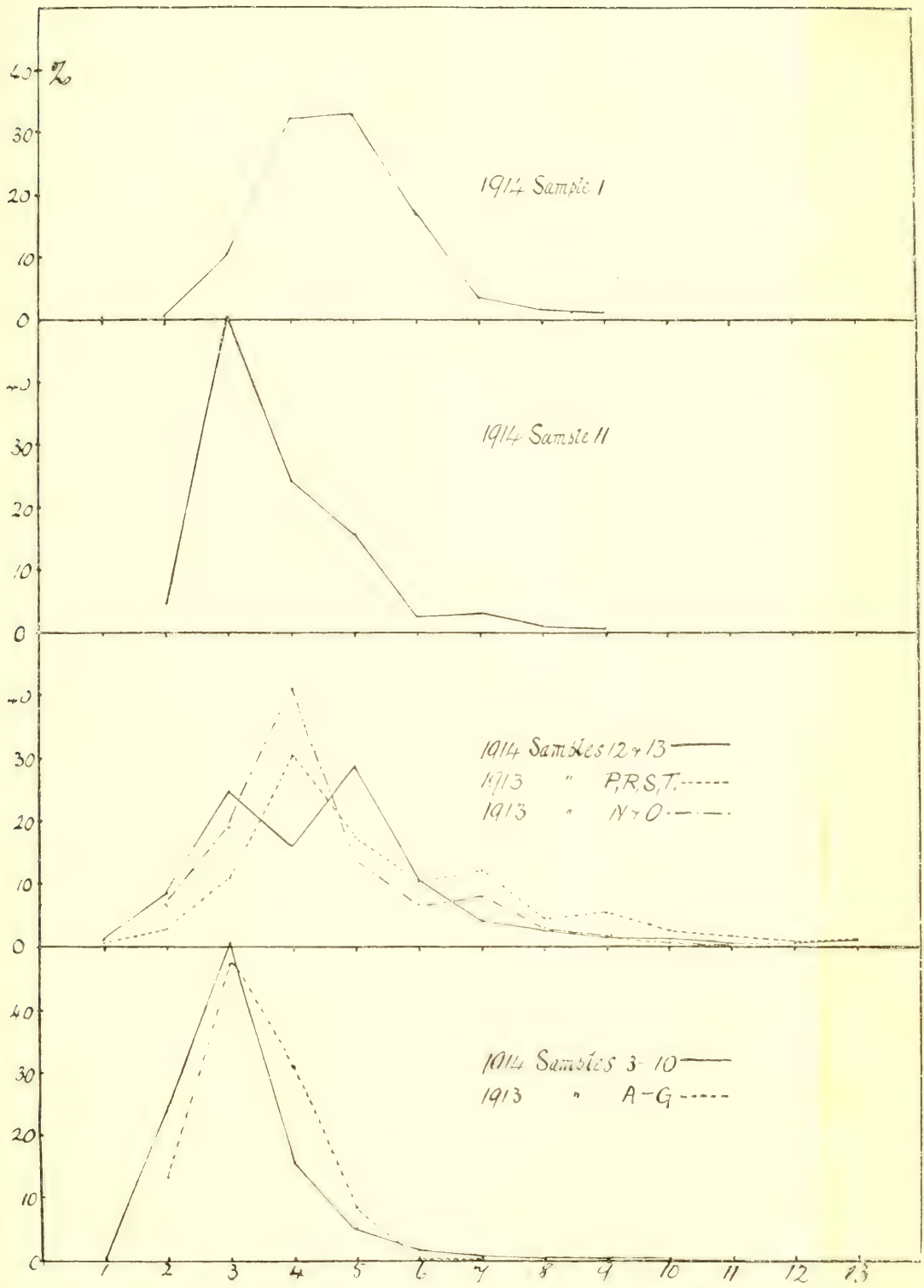
If the localities from whence the samples were obtained be arranged from north to south, and the age composition of the samples and the average size of the fish having from two to four winter rings be plotted irrespective of date of capture, as in Chart III., it will be seen that the locality of capture nearest the middle of the area from which the samples came furnished not only the greatest number of the youngest herrings but, generally speaking, the smallest fish for their age. This would seem to point to some segregation not only according to age but also according to size. The more rapidly grown younger herrings evidently joined those which were older, and the slower grown fish with three winter rings remained in the district where those with two winter rings were more plentiful. The curves drawn suggest that the regions which yielded samples 5 and 10 were similar to that from which sample 7 was obtained.

In the trawled herring samples the size of the fish according to age was practically the same as in 1913.

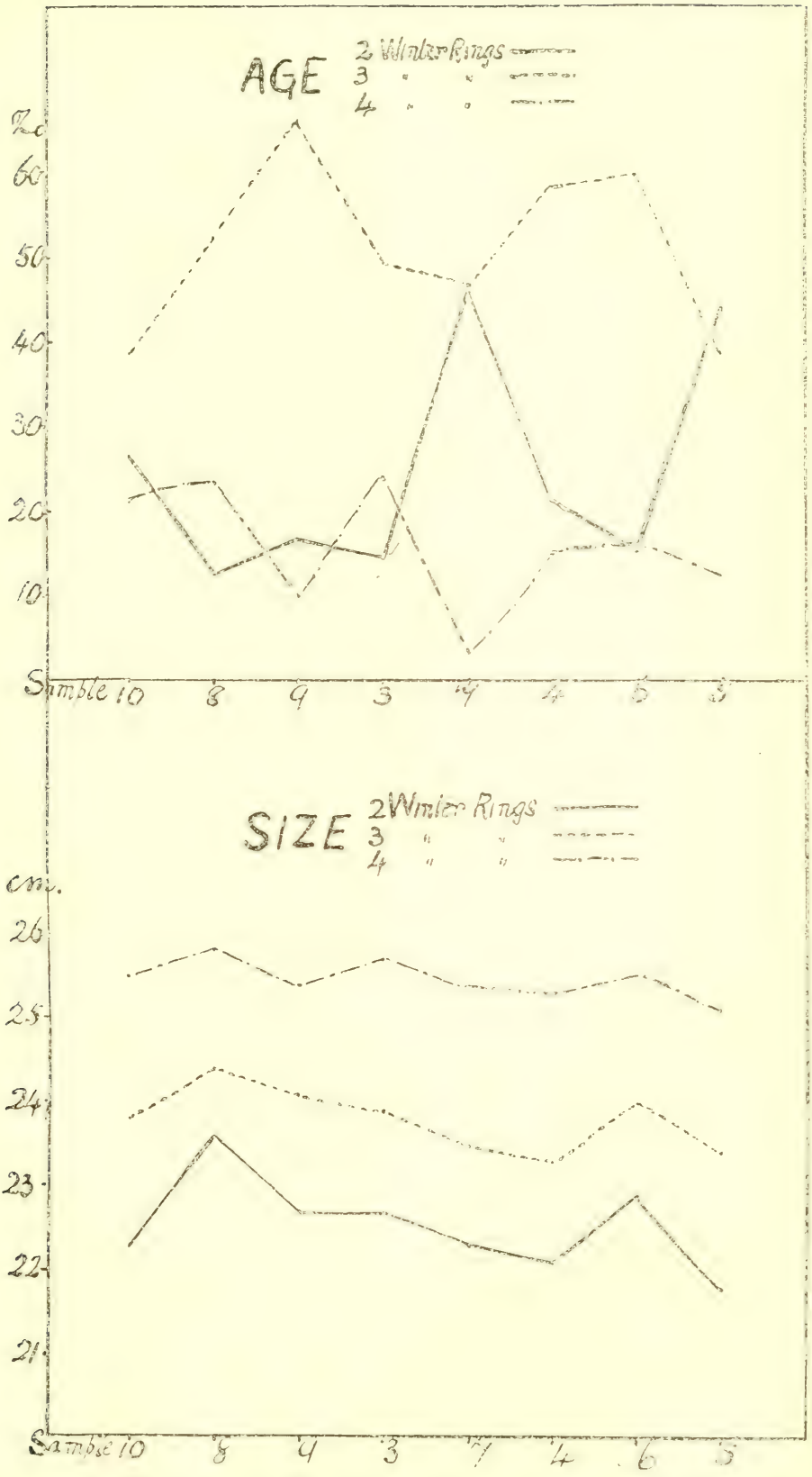
The Yorkshire coast drift net herring, sample 11, are of interest as the average size of fish with two winter rings was 24·7 cm., with three winter rings 25·2 cm., and with four winter rings 26·2 cm. They were larger for their age than any of our local herrings, and as has been pointed out the sample was captured further south than samples 3 to 10, and contained more older fish.

In sample 3 there was a fish with ten winter rings, the scales of which showed a smaller growth during the third year than the

HERRING INVESTIGATIONS.—CHART I.



HERRING INVESTIGATIONS.—CHART II.



HERRING INVESTIGATIONS.—CHART III.

fourth. The scales were therefore marked as those of the 1904 year-class marked herrings of Norway. The fish was a male at stage 2, and was 29·4 cm. long.

Maturity.—Table IV. The first sample consisted of recovering spents and virgin fish. The catching of the herrings for bait when line fishing made the time between capture and landing long, and as no ice was used for preserving the catch, the condition of the gonads presented difficulties in determining exactly the state of development. It was thought better, therefore, to enter all with small gonads of the shape and size of Hjort's stage 2 as two's, than to try and discriminate between stages 7—2 and 2, which could not have been done with any confidence.

Virgin fish formed practically the whole of sample 2, only four herrings being present at stage 2.

As would be expected from the age composition of samples 3 to 10, there was for 1914 as in 1913 no evidence of any spawning taking place in our local waters, which have already been referred to as a nursery for young herrings of from two to four winter rings. Although investigations in connexion with the herrings of the district have been carried on for a short time only, there is no doubt from the evidence obtained from fishermen and the occasional landings of haddocks gorged with herring spawn that our waters have at times been a spawning ground for the herring. But it does not follow that the spawning and the young fish belong to the same shoal, and it is more than probable that the nursery ground for one shoal has at times been used as a spawning ground by another shoal.

Sample 11 contained more fish at an advanced stage of maturity than were found in the Northumberland coast samples.

The trawled herring samples were similar as regards maturity to those of 1913. They contained a fair number of mature and spent fish, and also a number which were too young to spawn during 1914.

TABLE I.—SIZE.

CENTIMETRES.

Sample.		18	19	20	21	22	23	24	25	26	27	28	29	30
1	Nos.	—	—	—	2	15	24	26	138	171	64	20	6	—
	%	—	—	—	0·4	3·2	5·2	5·6	29·6	36·6	13·7	4·3	1·3	—
2	Nos.	—	3	18	39	48	42	16	5	—	—	—	—	—
	%	—	1·8	10·5	22·7	27·9	24·4	9·3	2·9	—	—	—	—	—
3	Nos.	—	—	1	2	18	46	69	42	41	22	6	3	—
	%	—	—	0·4	0·8	7·2	18·4	27·6	16·8	16·4	8·8	2·4	1·2	—
4	Nos.	—	—	3	15	44	74	64	22	15	9	1	—	—
	%	—	—	1·2	6·0	17·6	29·6	25·6	8·8	6·0	3·6	0·4	—	—
5	Nos.	—	1	9	38	53	61	37	27	16	3	3	—	—
	%	—	0·4	3·6	15·2	21·2	24·4	14·8	10·8	6·4	1·2	1·2	—	—
6	Nos.	—	—	—	1	17	57	78	48	28	10	7	1	—
	%	—	—	—	0·4	6·8	22·8	31·2	19·2	11·2	4·0	2·8	0·4	—
7	Nos.	—	—	5	16	63	85	50	19	7	1	1	—	—
	%	—	—	2·0	6·4	25·2	34·0	20·0	7·6	2·8	0·4	0·4	—	—
8	Nos.	—	—	—	—	2	36	75	63	55	13	4	1	—
	%	—	—	—	—	0·8	14·4	30·0	25·2	22·0	5·2	1·6	0·4	—
9	Nos.	—	—	1	3	19	58	86	51	20	8	1	2	—
	%	—	—	0·4	1·2	7·6	23·2	34·4	20·4	8·0	3·2	0·4	0·8	—
10	Nos.	—	—	4	14	34	59	39	42	39	13	3	—	1
	%	—	—	1·6	5·6	13·6	23·6	15·6	16·8	15·6	5·2	1·2	—	0·4
11	Nos.	—	—	—	1	1	8	27	38	59	40	17	7	3
	%	—	—	—	0·5	0·5	4·0	13·5	19·0	29·5	20·0	8·5	3·5	1·5
12	Nos.	—	—	—	4	1	9	27	36	54	38	23	3	2
	%	—	—	—	2·0	0·5	4·5	13·5	18·0	27·0	19·0	11·5	1·5	1·0
13	Nos.	—	—	2	7	11	12	15	31	37	39	30	12	4
	%	—	—	1·0	3·5	5·5	6·0	7·5	15·5	18·5	19·5	15·0	6·0	2·0

TABLE II—AGE.

WINTER RINGS.

Sample.		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Nos.	—	3	49	151	154	80	16	8	5	—	—	—	—
	%	—	0·6	10·5	32·3	32·9	17·1	3·4	1·7	1·1	—	—	—	—
2	Nos.	—	78	80	13	—	—	—	—	—	—	—	—	—
	%		45·6	46·7	7·7	—	—	—	—	—	—	—	—	—
3	Nos.	—	36	124	51	22	11	3	1	1	1	—	—	—
	%	—	14·4	49·6	20·4	8·8	4·4	1·2	0·4	0·4	0·4	—	—	—
4	Nos.	—	53	147	38	8	1	—	—	—	—	—	—	—
	%	—	21·2	58·8	15·2	3·2	0·4	—	—	—	—	—	—	—
5	Nos.	—	110	97	32	9	—	—	—	—	—	—	—	—
	%	—	44·0	38·8	12·8	3·6	—	—	—	—	—	—	—	—
6	Nos.	—	39	150	40	12	5	1	—	—	—	—	—	—
	%	—	15·6	60·0	16·0	4·8	2·0	0·4	—	—	—	—	—	—
7	Nos.	2	115	117	8	2	2	1	—	—	—	—	—	—
	%	0·8	46·0	46·8	3·2	0·8	0·8	0·4	—	—	—	—	—	—
8	Nos.	—	31	132	59	19	5	1	1	1	—	—	—	—
	%	—	12·4	52·8	23·6	7·6	2·0	0·4	0·4	0·4	—	—	—	—
9	Nos.	1	42	165	25	11	2	2	1	—	—	—	—	—
	%	0·4	16·8	66·0	10·0	4·4	0·8	0·8	0·4	—	—	—	—	—
10	Nos.	5	67	97	53	17	6	2	—	1	—	—	—	—
	%	2·0	26·8	38·8	21·2	6·8	2·4	0·8	—	0·4	—	—	—	—
11	Nos.	—	9	101	48	29	5	6	2	1	—	—	—	—
	%	—	4·5	50·5	24·0	14·5	2·5	3·0	1·0	0·5	—	—	—	—
12	Nos.	—	11	44	34	66	28	9	2	1	2	—	—	—
	%	—	5·5	22·0	17·0	33·0	14·0	4·5	1·0	0·5	1·0	—	—	—
13	Nos.	4	23	55	30	49	14	7	7	4	2	1	1	3
	%	2·0	11·5	27·5	15·0	24·5	7·0	3·5	3·5	2·0	1·0	0·5	0·5	1·5

TABLE III.—SIZE AND AGE.

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
1	2	—	—	—	—	3	—	—	—	—	—	—	—	—	3
	3	—	—	—	2	10	24	8	5	—	—	—	—	—	49
	4	—	—	—	—	2	—	15	75	49	9	1	—	—	151
	5	—	—	—	—	—	—	3	46	80	21	4	—	—	154
	6	—	—	—	—	—	—	—	12	40	21	6	1	—	80
	7	—	—	—	—	—	—	—	—	2	8	5	1	—	16
	8	—	—	—	—	—	—	—	—	—	4	1	3	—	8
	9	—	—	—	—	—	—	—	—	—	1	3	1	—	5
		—	—	—	2	15	24	26	138	171	64	20	6	—	466
2	2	—	3	13	31	23	8	—	—	—	—	—	—	—	78
	3	—	—	5	8	24	33	9	1	—	—	—	—	—	80
	4	—	—	—	—	1	1	7	4	—	—	—	—	—	13
		—	3	18	39	48	42	16	5	—	—	—	—	—	171
3	2	—	—	1	2	11	14	8	—	—	—	—	—	—	36
	3	—	—	—	—	7	32	57	23	4	1	—	—	—	124
	4	—	—	—	—	—	—	4	16	22	9	—	—	—	51
	5	—	—	—	—	—	—	—	3	12	3	3	1	—	22
	6	—	—	—	—	—	—	—	—	3	6	2	—	—	11
	7	—	—	—	—	—	—	—	—	—	2	1	—	—	3
	8	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	9	—	—	—	—	—	—	—	—	—	1	—	—	—	1
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	1	2	18	46	69	42	41	22	6	3	—	250
4	2	—	—	3	10	22	13	5	—	—	—	—	—	—	53
	3	—	—	—	5	22	60	47	11	2	—	—	—	—	147
	4	—	—	—	—	—	1	11	8	11	7	—	—	—	38
	5	—	—	—	—	—	—	1	3	1	2	1	—	—	8
	6	—	—	—	—	—	—	—	—	1	—	—	—	—	1
		—	—	3	15	44	74	64	22	15	9	1	—	—	247
5	2	—	1	9	35	41	20	3	1	—	—	—	—	—	110
	3	—	—	—	3	12	40	25	15	2	—	—	—	—	97
	4	—	—	—	—	—	1	9	10	10	1	1	—	—	32
	5	—	—	—	—	—	—	—	1	4	2	2	—	—	9
		—	1	9	38	53	61	37	27	16	3	3	—	—	248

TABLE III.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
6	2	—	—	—	1	10	19	8	1	—	—	—	—	—	39
	3	—	—	—	—	7	38	62	34	9	—	—	—	—	150
	4	—	—	—	—	—	—	8	12	13	5	2	—	—	40
	5	—	—	—	—	—	—	—	1	6	2	3	—	—	12
	6	—	—	—	—	—	—	—	—	—	3	2	—	—	5
	7	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	—	1	17	57	78	48	28	10	7	1	—	247
7	1	—	—	1	1	—	—	—	—	—	—	—	—	—	2
	2	—	—	3	15	53	35	8	1	—	—	—	—	—	115
	3	—	—	1	—	10	50	40	15	1	—	—	—	—	117
	4	—	—	—	—	—	—	2	2	3	1	—	—	—	8
	5	—	—	—	—	—	—	—	1	1	—	—	—	—	2
	6	—	—	—	—	—	—	—	—	2	—	—	—	—	2
	7	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	—	5	16	63	85	50	19	7	1	1	—	—	247
8	2	—	—	—	—	—	17	9	5	—	—	—	—	—	31
	3	—	—	—	—	2	18	60	38	11	2	1	—	—	132
	4	—	—	—	—	—	1	6	17	27	6	2	—	—	59
	5	—	—	—	—	—	—	—	3	13	3	—	—	—	19
	6	—	—	—	—	—	—	—	—	4	1	—	—	—	5
	7	—	—	—	—	—	—	—	—	—	—	1	—	—	1
	8	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	9	—	—	—	—	—	—	—	—	—	1	—	—	—	1
		—	—	—	—	2	36	75	63	55	13	4	1	—	249
9	1	—	—	—	1	—	—	—	—	—	—	—	—	—	1
	2	—	—	1	1	14	18	8	—	—	—	—	—	—	42
	3	—	—	—	1	4	40	72	38	8	2	—	—	—	165
	4	—	—	—	—	1	—	3	10	7	4	—	—	—	25
	5	—	—	—	—	—	—	2	3	3	2	—	1	—	11
	6	—	—	—	—	—	—	1	—	1	—	—	—	—	2
	7	—	—	—	—	—	—	—	—	1	—	—	1	—	2
	8	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	—	1	3	19	58	86	51	20	8	1	2	—	249

TABLE III.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
10	1	—	—	2	2	1	—	—	—	—	—	—	—	—	5
	2	—	—	2	9	24	28	4	—	—	—	—	—	—	67
	3	—	—	—	3	9	30	27	19	7	2	—	—	—	97
	4	—	—	—	—	—	1	6	17	23	5	1	—	—	53
	5	—	—	—	—	—	—	2	6	6	3	—	—	—	17
	6	—	—	—	—	—	—	—	—	3	2	1	—	—	6
	7	—	—	—	—	—	—	—	—	—	—	1	—	1	2
	9	—	—	—	—	—	—	—	—	—	1	—	—	—	1
		—	—	4	14	34	59	39	42	39	13	3	—	1	248
11	2	—	—	—	—	—	1	4	1	3	—	—	—	—	9
	3	—	—	—	1	1	7	21	27	29	12	3	—	—	101
	4	—	—	—	—	—	—	2	8	20	15	2	1	—	48
	5	—	—	—	—	—	—	—	2	5	13	6	3	—	29
	6	—	—	—	—	—	—	—	—	2	—	1	1	1	5
	7	—	—	—	—	—	—	—	—	—	—	2	2	2	6
	8	—	—	—	—	—	—	—	—	—	—	2	—	—	2
	9	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	—	—	1	1	8	27	38	59	40	17	7	3	201
12	2	—	—	—	4	1	3	1	2	—	—	—	—	—	11
	3	—	—	—	—	—	6	19	10	7	2	—	—	—	44
	4	—	—	—	—	—	—	4	14	11	5	—	—	—	34
	5	—	—	—	—	—	—	3	9	27	16	10	1	—	66
	6	—	—	—	—	—	—	—	1	9	9	8	1	—	28
	7	—	—	—	—	—	—	—	—	—	5	3	—	1	9
	8	—	—	—	—	—	—	—	—	—	1	1	—	—	2
	9	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	10	—	—	—	—	—	—	—	—	—	—	1	—	1	2
		—	—	—	4	1	9	27	36	54	38	23	3	2	197

TABLE III.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
13	1	—	—	1	2	1	—	—	—	—	—	—	—	—	4
	2	—	—	1	4	6	2	5	4	—	1	—	—	—	23
	3	—	—	—	1	4	9	9	19	9	4	—	—	—	55
	4	—	—	—	—	—	1	1	6	13	6	3	—	—	30
	5	—	—	—	—	—	—	—	2	12	22	9	4	—	49
	6	—	—	—	—	—	—	—	—	3	4	6	1	—	14
	7	—	—	—	—	—	—	—	—	—	1	5	1	—	7
	8	—	—	—	—	—	—	—	—	—	1	5	1	—	7
	9	—	—	—	—	—	—	—	—	—	—	—	3	1	4
	10	—	—	—	—	—	—	—	—	—	—	2	—	—	2
	11	—	—	—	—	—	—	—	—	—	—	—	—	1	1
	12	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	13	—	—	—	—	—	—	—	—	—	—	—	1	2	3
		—	—	2	7	11	12	15	31	37	39	30	12	4	200

TABLE IIIA.—SIZE AND AGE.

CENTIMETRES

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
A ...	2	—	—	—	2	4	1	—	—	—	—	—	—	—	7
	3	—	—	—	1	6	17	4	4	1	—	—	—	—	33
	4	—	—	—	—	3	6	6	7	3	—	—	—	—	25
	5	—	—	—	—	—	—	—	3	1	—	—	—	—	4
		—	—	—	3	13	24	10	14	5	—	—	—	—	69
B ...	2	—	—	—	1	2	1	—	—	—	—	—	—	—	4
	3	—	—	—	1	5	14	7	1	—	—	—	—	—	28
	4	—	—	—	1	—	7	4	6	2	—	—	—	—	20
	5	—	—	—	—	—	2	5	5	1	1	—	—	—	14
		—	—	—	3	7	24	16	12	3	1	—	—	—	66
C ...	2	—	—	1	8	8	9	2	—	—	—	—	—	—	28
	3	—	—	1	2	12	31	11	2	—	—	—	—	—	59
	4	—	—	—	—	—	2	7	6	3	—	—	—	—	18
	5	—	—	—	—	—	—	—	1	1	—	—	—	—	2
		—	—	2	10	20	42	20	9	4	—	—	—	—	107
D ...	2	—	—	—	6	5	3	—	—	—	—	—	—	—	14
	3	—	—	—	—	6	17	13	4	2	—	—	—	—	42
	4	—	—	—	—	—	5	6	9	1	1	—	—	—	22
	5	—	—	—	—	—	—	—	1	2	2	—	—	—	5
		—	—	—	6	11	25	19	14	5	3	—	—	—	83
E ...	2	—	—	—	—	—	9	2	2	—	—	—	—	—	13
	3	—	—	—	—	—	4	25	9	1	—	—	—	—	39
	4	—	—	—	—	—	1	6	11	1	1	—	—	—	20
	5	—	—	—	—	—	—	1	3	2	—	—	—	—	6
		—	—	—	—	—	14	34	25	4	1	—	—	—	78
F ...	2	—	—	—	—	1	4	1	1	—	—	—	—	—	7
	3	—	—	—	—	—	3	11	20	7	2	—	—	—	43
	4	—	—	—	—	—	—	6	17	12	—	—	—	—	35
	5	—	—	—	—	—	—	—	2	5	2	2	—	—	11
	6	—	—	—	—	—	—	—	—	—	—	—	—	—	1*
		—	—	—	—	1	7	18	40	24	4	2	—	—	97

* One at 31 cms.

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
G ...	2	—	—	—	—	1	2	5	1	—	—	—	—	—	9
	3	—	—	—	—	—	7	18	12	3	—	—	—	—	40
	4	—	—	—	—	—	—	7	24	11	1	1	—	—	44
	5	—	—	—	—	—	—	—	2	4	—	—	—	—	6
	7	—	—	—	—	—	—	—	—	—	1	—	—	—	1
		—	—	—	—	1	9	30	39	18	2	1	—	—	100
H ...	2	—	—	—	—	—	1	4	1	—	—	—	—	—	6
	3	—	—	—	—	—	4	21	16	8	1	—	—	—	50
	4	—	—	—	—	—	—	4	15	6	1	1	—	—	27
	5	—	—	—	—	—	—	—	1	1	1	—	—	—	3
	6	—	—	—	—	—	—	—	1	1	2	2	2	1	9
	7	—	—	—	—	—	—	—	—	—	1	2	—	—	3
	8	—	—	—	—	—	—	—	—	—	—	—	2	—	2
		—	—	—	—	—	5	29	34	16	6	5	4	1	100
I ..	2	—	—	—	—	3	2	1	—	—	—	—	—	—	6
	3	—	—	—	1	1	9	22	16	4	—	—	—	—	53
	4	—	—	—	—	—	1	6	15	5	2	1	—	—	30
	5	—	—	—	—	—	—	—	1	—	1	1	—	—	3
	6	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	7	—	—	—	—	—	—	—	—	—	1	—	1	—	2
	8	—	—	—	—	—	—	—	—	—	—	—	—	1	1
	9	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	12	—	—	—	—	—	—	—	—	—	—	—	—	1	1
		—	—	—	1	4	12	29	32	9	4	2	4	2	99
J ...	2	—	—	—	1	1	2	6	3	—	—	—	—	—	13
	3	—	—	—	—	—	10	43	31	10	—	—	—	—	94
	4	—	—	—	—	—	1	10	33	15	5	2	—	—	66
	5	—	—	—	—	1	—	—	4	5	4	2	—	—	16
	6	—	—	—	—	—	—	—	—	1	—	1	1	—	3
	7	—	—	—	—	—	—	—	—	—	—	3	—	2	5
	8	—	—	—	—	—	—	—	—	—	1	—	—	—	1
		—	—	—	1	2	13	59	71	31	10	8	1	2	198

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
K ...	2	—	—	—	1	6	15	3	3	—	—	—	—	—	28
	3	—	—	—	—	1	16	53	38	4	—	—	—	—	112
	4	—	—	—	—	—	—	12	19	11	2	2	1	—	47
	5	—	—	—	—	—	—	1	1	2	1	1	—	—	6
	6	—	—	—	—	—	—	—	—	2	—	1	—	—	3
	7	—	—	—	—	—	—	—	—	—	1	—	—	—	1
	13	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	—	1	7	31	69	61	19	4	4	2	—	198
L ...	2	—	—	—	1	6	7	11	6	—	—	—	—	—	31
	3	—	—	—	—	—	10	34	41	8	—	2	—	—	95
	4	—	—	—	—	1	—	11	32	16	4	1	—	—	65
	5	—	—	—	—	—	—	—	—	6	2	1	—	—	9
	6	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	8	—	—	—	—	—	—	—	—	—	1	—	—	—	1
	11	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	—	1	7	17	56	79	30	7	4	2	—	203
M ...	2	—	—	1	11	15	12	5	—	—	—	—	—	—	44
	3	—	—	—	1	2	9	14	18	4	1	—	—	—	49
	4	—	—	—	—	—	1	1	4	4	—	—	—	—	10
	5	—	—	—	—	—	—	—	1	—	—	—	—	—	1
	7	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	1	12	17	22	20	23	8	1	—	1	—	105
N ...	3	—	—	—	—	—	2	10	12	1	—	—	—	—	25
	4	—	—	—	—	—	1	16	47	24	9	1	—	—	98
	5	—	—	—	—	—	—	—	9	17	9	4	—	—	39
	6	—	—	—	—	—	—	—	—	1	6	4	2	—	13
	7	—	—	—	—	—	—	—	—	—	3	6	2	—	11
	8	—	—	—	—	—	—	—	—	—	1	—	2	1	4
	9	—	—	—	—	—	—	—	—	1	1	1	1	—	4
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	—	—	—	3	26	68	44	29	16	8	1	195

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
O ...	2	—	—	1	5	7	4	2	1	—	—	—	—	—	20
	3	—	—	—	—	4	12	14	10	2	—	—	—	—	42
	4	—	—	—	—	—	2	5	25	13	5	2	—	—	52
	5	—	—	—	—	—	—	1	—	4	6	2	—	—	13
	6	—	—	—	—	—	—	—	—	—	6	4	—	—	10
	7	—	—	—	—	—	—	—	—	1	2	8	4	2	17
	8	—	—	—	—	—	—	—	—	—	—	2	3	1	6
	9	—	—	—	—	—	—	—	—	—	—	—	1	1	2
	10	—	—	—	—	—	—	—	—	—	—	1	—	—	1
	11	—	—	—	—	—	—	—	—	—	—	1	—	—	1
		—	—	1	5	11	18	22	36	20	19	20	8	4	164
P ...	3	—	—	—	—	—	2	8	4	2	1	—	—	—	17
	4	—	—	—	—	—	—	5	25	17	8	5	—	—	60
	5	—	—	—	—	—	—	—	3	14	16	5	—	—	38
	6	—	—	—	—	—	—	—	—	2	5	9	1	—	17
	7	—	—	—	—	—	—	—	—	1	4	17	2	1	25
	8	—	—	—	—	—	—	—	—	—	3	5	4	1	13
	9	—	—	—	—	—	—	—	—	—	1	2	3	2	8
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	11	—	—	—	—	—	—	—	—	—	—	—	2	1	3
	12	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	13	—	—	—	—	—	—	—	—	—	—	—	3	2	5
		—	—	—	—	—	2	13	32	36	38	43	17	7	188
Q ...	2	—	—	—	7	9	4	—	—	—	—	—	—	—	20
	3	—	—	—	3	6	16	8	2	1	—	—	—	—	36
	4	—	—	—	—	1	1	14	24	6	3	—	—	—	49
	5	—	—	—	—	—	—	1	11	8	5	2	1	—	28
	6	—	—	—	—	—	—	—	—	3	2	—	—	—	5
	7	—	—	—	—	—	—	—	—	—	1	5	3	—	9
	8	—	—	—	—	—	—	—	—	—	—	1	2	—	3
	9	—	—	—	—	—	—	—	—	—	—	1	1	—	2
	11	—	—	—	—	—	—	—	—	—	—	1	—	1	2
	12	—	—	—	—	—	—	—	—	—	—	—	2	1	4*
	13	—	—	—	—	—	—	—	—	—	—	—	—	—	1*
		—	—	—	10	16	21	23	37	18	11	10	9	2	159

* One at 31 cms

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
R ...	2	—	—	—	—	—	2	—	—	—	—	—	—	—	2
	3	—	—	—	—	1	—	2	2	1	2	—	—	—	8
	4	—	—	—	—	—	—	1	15	11	3	2	—	—	32
	5	—	—	—	—	—	—	—	—	2	10	3	—	—	15
	6	—	—	—	—	—	—	—	—	1	4	7	2	—	14
	7	—	—	—	—	—	—	—	—	—	2	3	4	1	10
	8	—	—	—	—	—	—	—	—	—	2	—	1	1	4
	9	—	—	—	—	—	—	—	—	—	—	4	1	2	7
	10	—	—	—	—	—	—	—	—	—	—	1	—	1	2
	13	—	—	—	—	—	—	—	—	—	—	—	—	1	1
		—	—	—	—	1	2	3	17	15	23	20	8	6	95
S ...	1	—	—	—	1	—	—	—	—	—	—	—	—	—	1
	2	—	—	—	1	4	3	4	—	—	—	—	—	—	12
	3	—	—	—	—	1	9	11	6	1	—	—	—	—	28
	4	—	—	—	—	—	—	3	10	16	8	3	—	—	40
	5	—	—	—	—	—	—	—	2	9	14	4	1	—	30
	6	—	—	—	—	—	—	—	—	—	5	3	2	—	10
	7	—	—	—	—	—	—	—	—	1	6	14	2	—	23
	8	—	—	—	—	—	—	—	—	—	—	2	3	—	5
	9	—	—	—	—	—	—	—	—	1	—	—	2	1	4
	10	—	—	—	—	—	—	—	—	—	—	1	4	—	5
	11	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	12	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	—	2	5	12	18	18	28	33	27	16	1	160
T ...	2	—	—	—	—	—	1	1	—	—	—	—	—	—	2
	3	—	—	—	—	1	1	10	3	3	1	—	—	—	19
	4	—	—	—	—	—	—	4	17	15	7	3	—	—	46
	5	—	—	—	—	—	—	—	2	7	12	3	—	—	24
	6	—	—	—	—	—	—	—	2	2	3	10	2	—	19
	7	—	—	—	—	—	—	—	—	—	4	9	1	1	15
	8	—	—	—	—	—	—	—	—	—	—	1	2	1	4
	9	—	—	—	—	—	—	—	—	—	1	—	6	2	9
	10	—	—	—	—	—	—	—	—	—	—	2	—	3	5
	11	—	—	—	—	—	—	—	—	—	—	1	2	2	6*
	12	—	—	—	—	—	—	—	—	—	—	—	1	1	2
		—	—	—	—	1	2	15	24	27	28	29	14	10	151

* One at 31 cms.

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
U ...	2	—	—	2	3	7	2	1	1	—	—	—	—	—	16
	3	—	—	—	1	4	8	6	4	—	—	—	—	—	23
	4	—	—	—	—	—	2	7	10	13	3	—	—	—	35
	5	—	—	—	—	—	—	1	4	6	6	2	1	—	20
	6	—	—	—	—	—	—	—	—	1	1	6	2	—	13
	7	—	—	—	—	—	—	—	—	1	2	9	4	—	16
	8	—	—	—	—	—	—	—	—	—	2	2	4	1	9
	9	—	—	—	—	—	—	—	—	—	—	3	1	3	7
	10	—	—	—	—	—	—	—	—	—	—	2	4	2	8
	11	—	—	—	—	—	—	—	—	—	—	1	2	2	5
	12	—	—	—	—	—	—	—	—	—	—	—	1	3	4
	13	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	14	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		—	—	2	4	11	12	15	19	21	17	25	21	11	158
V ...	2	—	—	1	9	5	4	2	1	—	—	—	—	—	22
	3	—	—	—	—	—	2	5	4	2	1	—	—	—	14
	4	—	—	—	—	—	—	5	36	20	2	—	—	—	63
	5	—	—	—	—	—	—	—	4	18	8	3	—	—	33
	6	—	—	—	—	—	—	—	1	—	5	5	—	1	12
	7	—	—	—	—	—	—	—	—	—	—	—	2	—	2
	8	—	—	—	—	—	—	—	—	—	—	1	2	1	3
	9	—	—	—	—	—	—	—	—	—	1	2	3	1	7
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	12	—	—	—	—	—	—	—	—	—	—	—	—	1	1
	13	—	—	—	—	—	—	—	—	—	—	—	—	1	1
		—	—	1	9	5	6	12	46	40	17	11	8	5	160

TABLE IIIA.—*Continued.*

CENTIMETRES.

Sample	Winter Rings.	18	19	20	21	22	23	24	25	26	27	28	29	30	Total.
W ...	1	2	3	3	1	—	—	—	—	—	—	—	—	—	9
	2	—	1	10	15	15	11	1	—	—	—	—	—	—	53
	3	—	—	—	2	3	3	4	3	1	—	—	—	—	16
	4	—	—	—	—	1	1	6	5	4	—	—	—	—	17
	5	—	—	—	—	—	—	—	4	6	—	1	—	—	11
	6	—	—	—	—	—	—	—	1	1	2	—	—	—	4
	7	—	—	—	—	—	—	—	—	—	—	1	—	—	1
	8	—	—	—	—	—	—	—	—	—	—	—	2	—	2
	9	—	—	—	—	—	—	—	—	—	—	1	—	—	1
	10	—	—	—	—	—	—	—	—	—	—	—	1	—	1
	13	—	—	—	—	—	—	—	—	—	—	—	1	—	1
		2	4	13	18	19	15	11	13	12	2	3	4	—	116
X ...	2	—	—	—	3	8	6	2	1	—	—	—	—	—	20
	3	—	—	—	—	4	9	7	5	1	—	—	—	—	26
	4	—	—	—	—	—	1	10	14	9	3	1	—	—	38
	5	—	—	—	—	—	1	2	15	12	6	1	1	—	38
	6	—	—	—	—	—	—	—	—	—	2	—	1	—	3
	7	—	—	—	—	—	—	—	—	1	2	2	2	—	7
	8	—	—	—	—	—	—	—	—	1	4	—	1	2	8
	9	—	—	—	—	—	—	—	—	—	2	2	1	2	7
	10	—	—	—	—	—	—	—	—	—	—	2	5	—	7
	11	—	—	—	—	—	—	—	—	—	—	1	—	—	1
	12	—	—	—	—	—	—	—	—	—	—	—	1	—	2*
	14	—	—	—	—	—	—	—	—	—	—	—	1	1	2
		—	—	—	3	12	17	21	35	24	19	9	13	5	159

* One at 31 cms.

TABLE VI.—MATURITY.

Males.

Sample.	1	1—2	2	2—3	3	3—4	4	4—5	5	5—6	6	7	7—2	Total.
1	28	—	242	—	—	—	—	—	—	—	—	—	—	270
2	62	12	2	—	—	—	—	—	—	—	—	—	—	76
3	32	21	59	2	1	—	—	—	—	—	—	—	—	115
4	40	37	34	1	2	—	—	—	—	—	—	—	—	114
5	55	26	39	4	5	—	1	—	—	—	—	—	—	130
6	3	4	56	15	27	3	12	12	9	—	—	—	—	141
7	17	22	50	6	14	5	19	1	—	—	—	—	—	134
8	3	7	45	12	25	19	17	6	1	—	—	—	—	135
9	10	12	33	10	40	11	12	2	2	—	—	—	—	132
10	17	11	29	11	30	9	5	4	2	—	—	—	—	118
11	1	—	2	7	10	7	28	11	44	1	—	—	—	111
12	2	—	5	—	5	2	17	5	50	—	—	12	1	99
13	6	—	1	—	3	—	15	—	23	—	—	45	—	93

Females.

1	17	—	179	—	—	—	—	—	—	—	—	—	1	197
2	88	6	2	—	—	—	—	—	—	—	—	—	—	96
3	32	23	77	2	—	—	—	—	—	—	1	—	—	135
4	37	35	62	1	—	—	1	—	—	—	—	—	—	136
5	51	24	44	—	1	—	—	—	—	—	—	—	—	120
6	1	4	18	28	36	10	7	—	3	—	—	—	—	107
7	14	20	53	17	8	2	—	—	—	—	—	—	—	114
8	2	7	56	22	23	4	1	—	—	—	—	—	—	115
9	12	2	51	20	27	2	4	—	—	—	—	—	—	118
10	25	16	41	20	22	3	2	—	1	1	—	—	—	131
11	—	—	1	2	4	4	27	18	35	2	1	—	—	94
12	1	—	6	1	32	5	21	6	12	—	1	14	2	101
13	8	1	4	1	29	10	16	—	7	—	—	31	—	107

MIGRATIONS OF THE DAB.

By ALEXANDER MEEK.

In the following table three further recaptures of the dabs marked in 1913 are recorded. One of these, No. 1,356, which we owe to the Board of Agriculture and Fisheries, was only 22 cms. when liberated, and measured at its recapture more than a year afterwards 29 cms., and like the other immature members of the Northumberland school of dabs, it had migrated to the south. The others are large mature examples, measuring 36 and 37 cms., and in both cases they indicated a migration to the north. In last year's report, several examples of such a migration were recorded, and for the first time, because in previous years the marking had been confined for the most part to small immature fish.

It will be necessary when times are more favourable to make further experiments to obtain further facts, but in the meantime, it is permissible to conclude, in the light of the facts obtained by the Northumberland experiments and the earlier experiments of Fulton, that the dabs migrate in the immature condition on the north-east coast of England and the east coast of Scotland in a southerly direction offshore for winter, and in a northerly direction inshore for summer, and when mature they migrate northwards. The spawning migrants, after spawning, appear to migrate inshore, and probably migrate southwards before maturity calls them to the north again.

MIGRATIONS—DAB.

Where Caught.	Where Liberated.	Date.	Nos.	No.	Size.	Where Recaptured.	Date.	Length.	Sex.	Migration.
Almmouth Bay	Druridge Bay	1913. July 11	1301–1359 59	1337	Cm. 37 × 20	Almmouth Bay	Aug. 7th, 1914	Cm. 38	F.*	3 miles north.
Almmouth Bay	Druridge Bay	July 11	1301–1359 59	1356	22 × 11	½ mile E. of Scarborough Lighthouse	Sept. 11th, 1914	29·1	F.	85 miles south.
Almmouth Bay	Druridge Bay	Sept. 9	1433–1449 17	1440	36 × 20	3 miles E.S.E. of Holy Island	Sept. 2nd, 1914	37·3	F.	24 miles north.

* Label only.

MIGRATIONS OF THE LOBSTER AND THE CRAB.

By ALEXANDER MEEK.

Lobster.—From the reports we have published from year to year it will be evident that we have attempted at different times to mark lobsters with a view to obtaining some direct information as to their migrations. The results are not at all definite, but so far as they go, they may be said to point to a migration of the females when they become mature to a short distance northwards on the east coast.

During the last year or two it has been our habit to mark the lobsters used in the Laboratory for lobster culture after the larvæ have been liberated, and the shell has been cast. Although they were kept in a condition of confinement for several months, they were liberated as soon as they were hard enough after ecdysis to bear the label. Of a number marked in 1913, the results as published in the last report indicated migrations of the females to a mile or two to the north. This year, No. 270 was returned to us on June 2nd in the berried condition. She was liberated on August 18th, 1913, in Cullercoats Harbour, and was recaptured just to the south of St. Mary's Island, a little over two miles to the north. Her size at the time of recapture was 29 cms.

This specimen is interesting for two reasons; first, that it gives definite information as to the period intervening between casting and coming into berry, and, secondly, that it indicates at least a slight migration to the north of the mature females. None of the males which have been marked has, as in the case of the crabs, indicated any tendency to migrate.

Crab.—The last two reports gave the results of the marking of crabs at Beadnell at the end of 1912. An interesting example came into our hands this year. This was a female, No. 428, which was marked on December 1st, 1912, at Beadnell, and which was recaptured two miles east of Dunbar on April 26th, 1915. It will be noted that she was liberated just after an ecdysis, that the

shell had not been cast again at least for over two years, and that similarly the ripening of the ova was postponed. In this particular example the ovary was still in an ill-developed condition, although the spermathecæ were full. When recaptured she measured 15·2 cms.

A REMARKABLE CASE OF "PARENTAL" CARE IN THE GENUS COTTUS.

By ALEXANDER MEEK.

In April this year (1915) it was found that a Cottus had laid eggs in one of our tanks, and that a small Cottus had mounted guard over them. It was presumed that the eggs had been laid by one of two large Cottus, and that the specimen which watched them so assiduously was a male. An attempt was made to obtain a picture of the mass of eggs and the guardian, but they were too awkwardly placed, and both were removed to a glass vessel for the purpose. But this spoilt the charm entirely. In the confined new quarters the Cottus would not look at the eggs, and I have made an attempt in the figure reproduced here to give an indication of one of the usual positions assumed by the guardian.

A closer examination was now made of the Cottoids concerned. They consisted of the two large specimens, which we found to be mature spent females of *Cottus scorpius*, and the one which had guarded the eggs, and it turned out to be an immature female *Cottus bubalis*. The presumption is then, and it is supported by the evidence of the Laboratory attendant, that the eggs were laid by one of the *Cottus scorpius*, and that the immature female *Cottus bubalis* at once assumed the position of guardian. She was frequently found supporting herself on her pectoral fins between the glass and the wall of the tank, with the eggs just in front of her head. Whether she was there or in some other part of the tank when an object, such as a net or brush, was introduced, she at once swam out at it, and placed herself between the object and the eggs, and in every way behaved in the manner so common in the males of species of fish which lay demersal eggs.

From further enquiries it appears that both the *Cottus scorpius* spawned in the tank in which they had remained during the winter, and that the *Cottus bubalis* was introduced before the second mass of eggs was laid. It need not be said that both masses were unfer-

PARENTAL CARE IN THE GENUS COTTUS.

tilised. It is more than probable that the male Cottus guards the eggs, although the fact has never been observed definitely, at all events in the marine species. Here we have an example of an immature female actuated by the same impulse. The females which laid the eggs did not take any further interest in them.

We have not much knowledge of the behaviour of the parents with reference to the care of the eggs in Cottoids. In the case of *Cottus gobio*, Marsigli stated that the female scooped out the cavity in which the eggs were laid, and afterwards watched over them. From information derived from fishermen, also of the Danube region, Heckel and Kner said that the male *Cottus gobio* prepared the nest, and watched the eggs. Day states that the male *Cottus scorpius* is said to make a nest of seaweed and shells for the reception of the spawn, which he is also believed to watch over, and to protect the young when hatched.

SOME NEW POINTS ON AUTOTOMY AMONG THE DECAPOD CRUSTACEA.

By J. HERBERT PAUL, M.A., B.Sc.,
Barbour Research Scholar in Physiology at the University of Glasgow.

The self-amputation of injured parts by different animals has been described and recorded since the fifteenth century, but it was only at the end of the eighties of last century that exact observations were made. Fredericq * then analysed the process of autotomy in *Carcinus moenas*, paying special attention to the neuro-muscular mechanism and the structure of the breaking-joint at the limb-base, but since his time very little real knowledge has been added to the subject.

In the shore-crab, autotomy is seen in its most highly developed form. It is a unisegmental reflex, for it occurs when the nerve cord above and below the segment of injury is cut. If a leg be cut, crushed, burned, or otherwise severely damaged at any point central to the terminal segment, it is immediately extended against the carapace, and usually snaps off at a groove in the second segment or basi-ischium called the breaking-plane. If the crab be suspended by one of its legs, and the necessary stimulus for autotomy applied, it at once drops to the ground, leaving the part of damaged limb distal to the breaking-plane in the hand of the operator.

It would be natural to conclude that the region of the breaking-plane is the weakest part of the leg, but Fredericq demonstrated that this is not the case. He suspended a crab by one of its legs, and attached weights to the body till the leg was torn off. The break occurred at the joint between the body and the first segment, and not at the breaking-plane. The rupture surface was large and irregular, and division took place only when many times the body weight had been added.

Fredericq attributed the process of self-amputation to vigorous contraction of the long extensor muscle of the second limb segment,

and contact of the distal part of the limb with some point of resistance. A glance at his figures reproduced below gives the reader a better idea of his explanation than verbal description. (Figs. 1 and 2.)

He maintained that the long extensor, alone, was involved in autotomy, and that the break occurred cleanly, through solid calcareous integument.

The present writer,† in a comparative study of autotomy in the Decapod group (a group admirably suited for such study, because of the intense specialisation in various directions) found a somewhat different explanation than that of Fredericq. This was the result of a new method of analysis, viz., graphic recording of the various muscle contractions, correlated with exact examination of the anatomy of the basal limb-segments.

The principles of autotomy in the walking legs of some of the Macrura are the same as those seen in the more specialised Brachyura. A description of self-amputation as it occurs, for example, in the walking-legs of the common lobster, *Homarus vulgaris*, will probably make explantion of the phenomenon as it is seen in the shore-crab more easy.

The average loss of legs in the lobster is comparatively small, probably about 5 per cent. (Herrick) ‡, but the loss of walking-legs alone is much smaller. In lobsters taken from the sea it is perhaps only 1 or 2 per cent.

In a paper referring to autotomy in the crayfish, Reed § draws attention to the fact that if walking legs be cut sharply by scissors no autotomy occurs. She states, however, that if the legs are held by the scissors the limb is usually torn off at the free joint between the second and third limb-segments. I have examined this process in the crayfish, and find that it agrees in every point with what is described below for the lobster.

Anyone who has even casually observed the habits of lobsters in captivity or in the sea knows how effective the powerful abdominal flap is in removing the animal from any source of danger. This means of escape is also seen to be an essential factor in the production of autotomy of the walking-legs, for, if the limb is seized and crushed by strong pincers, it is usually abandoned in the region of the second joint at the moment the abdominal flap occurs, the basal segments at the same time being markedly extended.

In order to demonstrate the method by which the lobster is able to escape at the expense of the loss of a leg, it will be necessary to examine the structure of the basal parts of the limb.

The second segment consists roughly of a hollow triangular pyramid hinged at two of its points to the first segment (figs. 3 and 4). Ventrally, a flexor muscle has its tendon attached to the lower border, while dorsally, an extensor from the rounded edge (which represents two sides of the pyramid base) passes into the cavity of the first segment (fig. 4, *e*).

The inner side of the dorsal wall of the second segment is the origin of a muscle which is inserted by a small tendon into the ventral edge of the third segment. This muscle (fig. 5, *a*), by its insertion, may be regarded as a flexor, but since movement between the second and third segments is very limited, it probably does not function as such. Its important rôle in the production of autotomy gives reason for it being called the "autotomiser."

The third segment articulates with the second by a hinge joint. At the point of attachment of the muscle described above, a furrow begins at its lower edge and passes round the greater part of the limb at a distance of about 1 mm. from the arthrodial membrane of the third joint (figs. 3, 4 and 5, *f*).

After autotomy has occurred the appearance of the limb stump is as shown in fig. 8. A ring of calcareous material (*b*), corresponding to the part of the third segment central to the groove, is found attached to the stump. The autotomiser (figs. 6, 7 and 8, *a*) is contracted, and thus the ring is pulled into the cavity of the second segment, where it is often hidden among the soft tissues. This probably accounts for the fact that previous workers have not noticed it. Division of the limb therefore takes place along the groove at the base of the third segment, and where that groove ends, along the arthrodial membrane joining segments two and three.

The factors controlling autotomy were revealed by the following experiments :—

(1) Division of the extensor muscle of the second segment prevented it from occurring.

(2) Division of the flexor muscle of the third (the autotomiser) had the same effect.

(3) Cutting of the nerve cord to the tail also prevented it.

(4) Cutting of the nerve to the limb at its point of emergence from the central cord prevented it.

The process was further investigated as follows :—The tendon of the extensor muscle of the second segment was cut, and its end attached to a heart lever writing on an ordinary physiological drum, the lobster being secured on its back on a frog-board. A record of the reflex contraction, when the cut end of the limb was electrically stimulated, shows a latent period of ·13 secs. and presents the appearance shown in fig. 9.

The tail, or properly speaking the abdomen, which flapped violently after each stimulation was also connected up to a lever, and a record of its contraction made along with the contraction of the extensor of the second segment. A time relation of about four seconds exists between the two events (fig. 10).

Owing to the inaccessibility of the tendon of the autotomiser, I was unable to record the time of its contraction and its latent period, but I believe that it contracts after the extensor of the second segment and before the tail-flapping begins.

The following conclusions can be drawn from the above study of the process of autotomy of walking legs in the lobster.

The break occurs at a definite plane in the limb base. It passes partly through brittle calcareous material at the region of the groove in segment three, but also partly involves the tough arthrodial membrane between segments two and three. A noxious stimulus applied to the limb causes extension of the second segment, and at the same time, contraction of the autotomiser tends to draw the portion of segment three central to the groove, inwards. This causes weakening in the plane of the groove, and if the traction set up by tail flapping cannot be resisted, division of the limb occurs (figs. 6, 7 and 8).

The records of muscle contraction in the basal parts of the limb and in the tail establish the fact that the reflex is due to definite contractions, co-ordinated in time and degree. The reflex is pluri-segmental, for autotomy does not occur when the nerve connection to the tail is severed. If the influence of upper neurons be removed the reflexes are more brisk. This demonstrates that even in an animal with so little cerebral development as the lobster the inhibitory action of the upper ganglia is manifest.

It has been stated that it is necessary that a walking-leg be held in order that autotomy may be effected. This points to the probability that in the lobster and its allies evasion of an enemy is the most potent factor in the production of autotomy. This is borne out by the fact that lobsters when kept together in captivity are almost invariably found short of one or more legs after some time, because of the constant fighting. In those taken from the sea, where encounters cannot be so frequent, the loss is, as before-mentioned, comparatively small.

In the Brachyura escape or damage in fighting is not the chief end of autotomy, for fifty or more will live in one tank for many days without a single limb being cast off. This is at first puzzling when the following tables are examined :—

Shore Crabs collected at Cullercoats, Northumberland, January, 1915, from Rocky Shore.

Number.	Breadth of Carapace in cm.	Number with Legs missing.	%	Average Loss of Legs per Crab.
37	Over 5½	18	48·6	2
29	,, 4	7	24·1	1·2
40	Under 4	9	22·5	1·1

Shore Crabs collected from Rocky Shore at Keppel, Millport, March, 1913.

Number.	Carapace in cm.	Number with Legs missing.	%
22	4½—3½	11	50
26	3½—2½	6	23
14	2½—2	4	28
13	2—1½	...	...

From the above it is seen that in medium-sized and large crabs about 50 per cent. have lost one or more legs. The explanation of this great loss almost certainly lies in the fact that on the shores where these animals live there is, in winter, a constant

moving of stones by heavy seas. The crabs must therefore be constantly exposed to the risk of having their limbs crushed, and so of losing much blood. If autotomy at the breaking plane occurs at once, practically no hæmorrhage follows, for a very effective venous valve comes into operation at the moment of amputation. This has been described by the writer † in another place. Self-amputation of limbs in the Brachyura is therefore more a device for saving blood than for evading an enemy.

Fredericq's explanation of autotomy has been given above, but it has been found that it does not hold for all positions of the limb. For example, if the leg be forcibly extended, it cannot be cast off, and then, according to Fredericq's theory, it ought to be most easily autotomised.

A few words on structure are necessary in advancing the present explanation of self-amputation in the Brachyura. The form of the basal limb segments is almost uniform for the various "true crabs." In all cases the second segment or basi-ischium is divided by a furrow (the breaking-plane) into two parts. It is connected by muscles to the first segment and to the body wall, the short extensor and the short flexor moving it on the first segment, and the long extensor and long flexor joining it to the body. The bodies of these last-named muscles pass through the cavity of the first segment. Figs. 11 and 12 show this arrangement diagrammatically from the lateral aspect, and looking through the limb cavities, respectively.

The tendon attachments of the extensor muscles are of great importance in this description of the autotomy process, and they must be described in some detail. In the upper division of arthrodial membrane of the articulation between the first and second segments, the tendons may be seen shining through in the region of their attachment to the lower edge of the basi-ischium (fig. 13). The long extensor is atttached anteriorly and the short posteriorly. Between the attachments a knife can be passed upwards to the breaking-plane through tough material, which is not brittle and calcareous like the rest of the basium. This passage made by the knife is really through a slanting joint in the hard ring of integument forming the basium. It is shown in section in fig. 14.

The action of the short and long extensors is in directions shown in fig. 15, and when the muscles contract together, they

tend to pull different segments of the limb in directions shown in figs. 16 and 17. The result, of course, must be great weakening along the breaking furrow, and if a slight force is applied laterally the portion of the limb distal to the furrow snaps off.

To prove the above, a knife was inserted firmly between the insertions of the extensors, forcing the segments apart as indicated in fig. 18. The limb snapped off on the slightest lateral force being applied. When the knife was not inserted no amount of twisting and pulling could accomplish division at the seat of election.

That the extensor muscles contract separately and with slightly different latent periods is shown by figs. 19 and 20.

Thus, autotomy in the Brachyura is seen to be due to co-ordinate action of the basal muscles attached to the second segment, and to follow weakening in the region of the breaking plane. It is the result of a unisegmental reflex, and its chief purpose is to prevent hæmorrhage.

It is interesting to note the points of similarity and difference between this peculiar reaction to injury in two large branches of the Decapoda, like the Macrura and Brachyura, and to examine the effects of habits and habitat on the behaviour of the animals.

In the lobster, where the natural loss of legs is comparatively small, the act of autotomy is pluri-segmental, and resembles closely the animal's ordinary procedure when escaping from an enemy. Evasion is therefore its main purpose. In crabs, where the reflex arc is confined to one segment of the nervous system, hæmostasis seems to be the chief end. The liability to crushing of limbs on a stony shore is evidently great, for as a rule half the mature crabs collected in certain places have autotomised.

This tendency to localisation of mechanisms for protection in one part of the nervous system is a general principle of animal life, and the more a reaction tends to preserve the life of an individual, the more is it liable to be so localised. The benefit attained is, of course, more speed in performance of the act. For example, in the lobster, where impulses must travel through several neurons to ganglia controlling the tail, the latent period for reaction is about four seconds. In the highly specialised Brachyura, where liability to injury is very much greater, only a fraction of a second intervenes between injury and autotomy.

From a morphological view-point, too, there is interesting difference between the mechanisms of the two groups.

Lobsters effect the amputation by weakening of the limb at the breaking-plane, but removal is partly by snapping of a brittle substance, and partly by tearing through tough membrane. This, of course, pre-supposes a traction force on the abandoned part of the limb. Crabs, on the other hand, so weaken the region of the breaking-plane that the least force applied either by holding or by contact with an external object immediately causes the leg to snap off, the break, in all cases, being entirely through brittle integument, giving efficient support to the valve flaps which immediately come into action.*

Much of the observation connected with the above work was carried out at the Dove Laboratory, Cullercoats, and I have to thank Professor Meek for the facilities he has given me for working there. The rest of the work was done at the Marine Biological Station, Millport, and there Mr. R. Elmhirst extended to me his usual courtesy. Mr. J. Peden also gave valuable help in the making of records.

Professor Noël Paton, under whose supervision I have worked for some time, constantly encouraged and aided me in my experiments, and to him, again, I tender my sincere thanks.

SUMMARY.

(1) Autotomy of the walking-legs in the lobster and its allies is not a simple tearing at the third joint as other writers have stated, but is the result of a pluri-segmental reflex, which, among other things, causes great weakening of the limb at the central end of the third podomere along a groove running partly round the limb at this point.

(2) This weakening is caused by a definite muscle which is described.

(3) Autotomy of walking-legs in the lobster occurs about four seconds after nocuous stimulation. In the Brachyura there is a latent period of only a fraction of a second.

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* The existence of a breaking-plane as a structural entity has not been forgotten, and I intend to investigate its comparative morphology.

(4) The object of autotomy in the lobster is escape, whereas in crabs arrest of hæmorrhage must be regarded as the end.

(5) A new description of the mechanism and nature of autotomy in Macrura and Brachyura is given.

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* FREDERICQ, L. "Nouvelles recherches sur l'autotomie chez le crabe." *Arch. de Biol.*, t. xii., 1892.

† PAUL, J. H. (*a*) "Regeneration of the legs of decapod crustacea." *Proc. Roy. Soc. Edin.*, vol. xxxv., Dec., 1914.

(*b*) "A comparative study of the reflexes of autotomy in decapod crustacea." *Ibid.*, June, 1915.

‡ HERRICK, F. H. "The American Lobster," *Bull. U.S. Fish Commission*, 1895.

§ REED, M. A. "Regeneration of the first leg of the crayfish." *Arch. f. entw.*, t. xviii., 1904.

EXPLANATION OF FIGURES.

Figs. 1 and 2 (after Fredericq).

Showing how he explained autotomy in *Carcinus mœnas* by violent contraction of the long extensor, and contact of the distal part of the limb with the carapace or other resistant object.

Figs. 3 and 4.

Showing the basal limb-segments in the walking-leg of *Homarus vulgaris*.

e = Extensor muscle of segment two.

f = Breaking furrow at the central end of segment three.

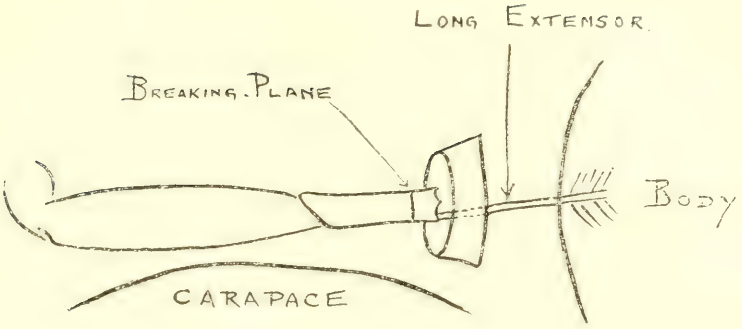

FIG. 1.

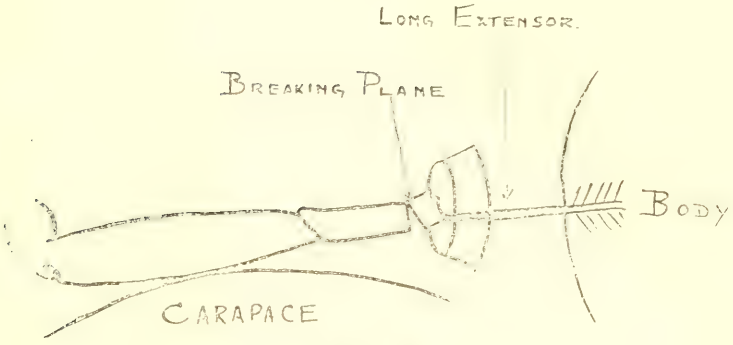

FIG. 2.

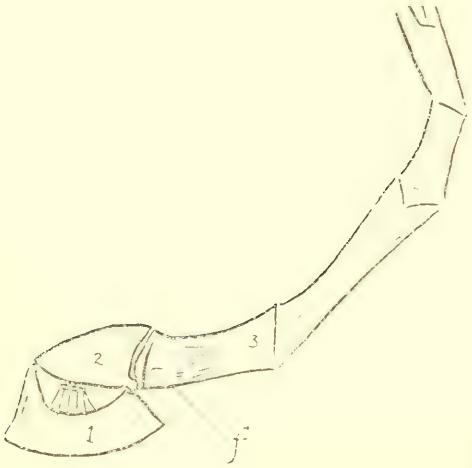

FIG. 3.

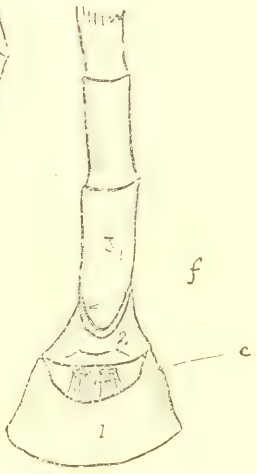

FIG. 4.

FIG. 5.

Diagram showing origin and insertion of the autotomiser.

a = Autotomiser.

f = Breaking furrow.

FIGS. 6, 7 and 8.

Showing the condition of the basal segments, before, during and after autotomy.

a = Autotomiser muscle.

f = Breaking furrow

b = Ring of integument broken off from segment three when autotomy occurs.

FIG. 9.

Copy of tracing showing reflex contraction of the extensor of the second segment during autotomy.

A = Point of stimulation.

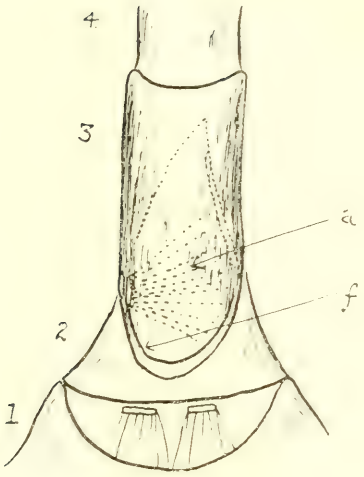

Fig. 5.

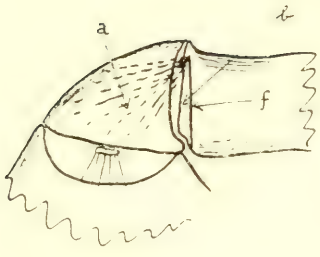

Fig. 6.

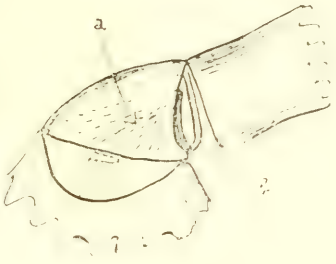

Fig. 7.

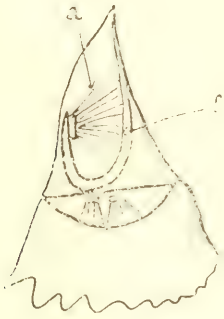

Fig. 8.

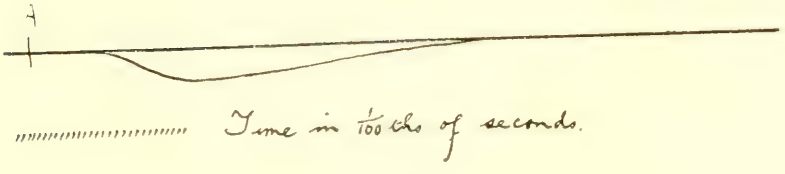

Fig. 9.

Fig. 10.

Copy of tracings showing reflex contraction of the extensor of the second segment and of the abdominal muscles. Note the difference in latent period of about four seconds.

Figs. 11 and 12.

Diagrams showing the arrangement of tendons inserted into the central end of the basi-ischium of a Brachyuran.

Bp = Breaking plane.

lf = Long flexor.

le = Long extensor.

sf = Short flexor.

se = Short extensor.

Fig. 12 is after Fredericq.

Fig. 13.

Showing anatomy of the limb in the region of the breaking plane in an edible crab.

Bp = Breaking plane.

le = Long extensor.

se = Short extensor.

The dotted line through *a* shows the direction in which a knife can be passed up to the breaking plane.

Fig. 14.

Diagram of transverse section through limb at level of breaking plane showing attachment of the extensors on either side of the slanting joint *a*.

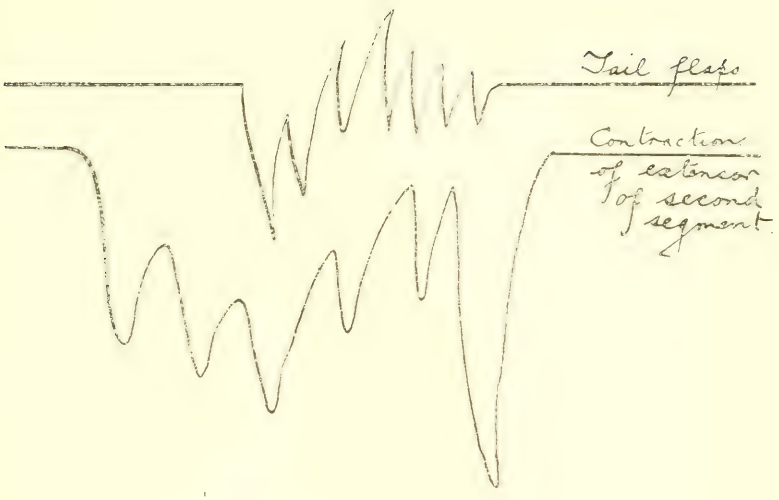

FIG. 10.

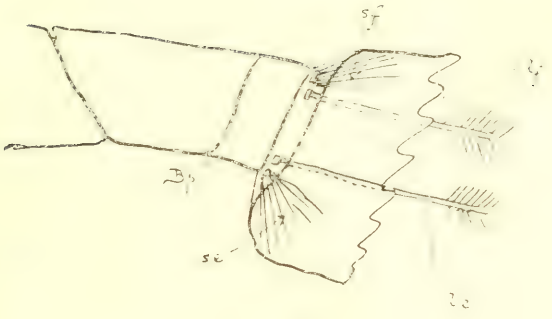

FIG. 11.

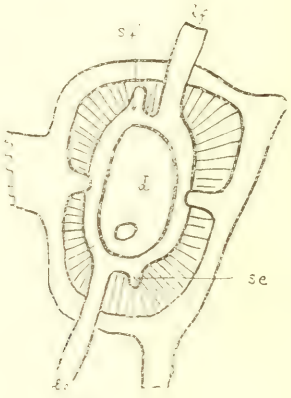

FIG. 12.

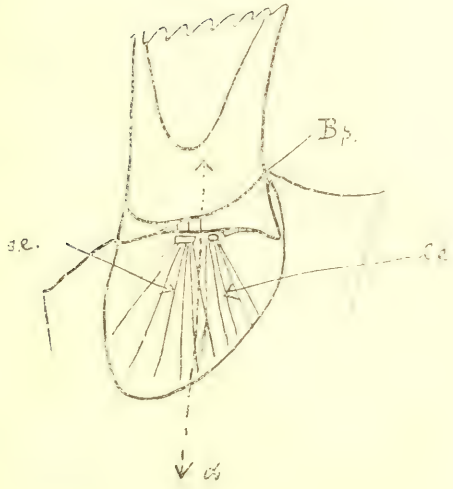

FIG. 13.

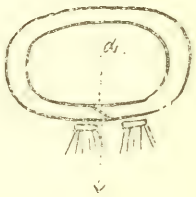

FIG. 14

Figs. 15, 16, 17.

Diagrams showing the direction and result of action of the long and short extensors on the basium.

Fig. 18.

A knife pressed between the segments of the basium, as indicated, produces the same weakening as the contractions of the extensors.

Fig. 19.

Copy of tracing showing contraction of the combined tendon of the extensors. Notice the double element in the curve.

A = Point of stimulation.

Fig. 20.

Copy of superimposed tracings of reflex contractions of the extensors Notice the difference in the latent periods.

(1) = Long extensor.

(2) = Short extensor.

A = Point of stimulation.

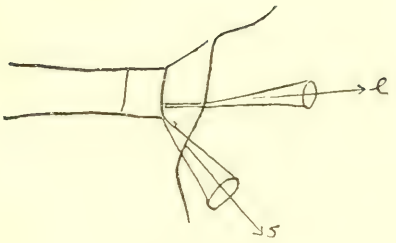

FIG. 15.

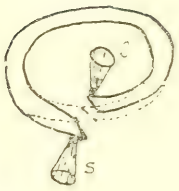

FIG. 16.

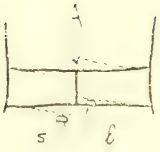

FIG. 17.

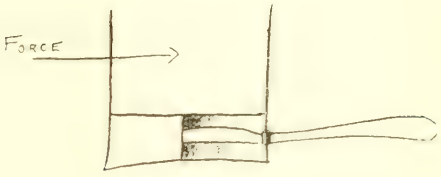

FIG. 18.

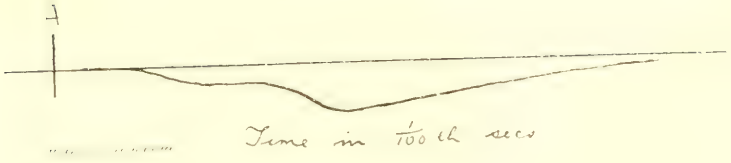

FIG. 19.

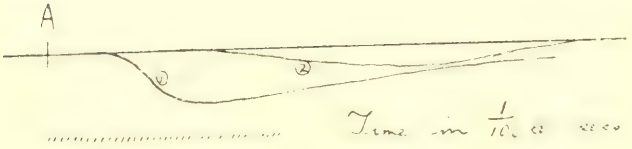

FIG. 20.

NOTE ON A HÆMOGREGARINA OF *RAIA BATIS*.

By T. BENTHAM, M.Sc.

While dissecting a small specimen of *Raia batis* in March last, a single smear of blood was taken from the auricle. This was stained overnight with Giemsa's solution, after fixing for a quarter of an hour in absolute alcohol. The erythrocytes were found to be infected with a small species of Hæmogregarina. Sometimes the parasite was found free in the plasma. The average length of the organisms was about 7 μ, their breadth 2 μ at the thickest part of the cell. They were usually found lying in the cytoplasm of the erythrocyte, parallel to the long axis of the corpuscle, and they did not displace the nucleus. The parasite was sickle-shaped, pointed at one end, and rounded at the other. There was a large centrally placed nucleus, and at the rounded end a conspicuous vacuolar space. The rest of the cytoplasm contained numerous grains of volutin, or some such substance, and situated near to the vacuole were as a rule two large conspicuous organellæ, probably consisting of this substance. In a good many cases two parasites were found in a single erythrocyte, and these always lay parallel to one another, suggesting binary fission. In this the organism resembles *Hæmogregarina bigeminum* from the blood of different species of blennies. The parasites were enclosed in a distinct capsule, which was somewhat thickened at both ends. Often from shrinkage of the parasite the edge of the capsule was distinctly visible. Previously, the only species of Hæmogregarine described was from the blood of *Raia mosaica*. Double infection and size, however, point to the fact that the parasite is closely allied to *H. bigeminum*.

THE AGE AND GROWTH OF THE PILCHARD.

By B. STORROW.

The presence of a pilchard in a sample of herrings from 18½ miles S.E. by E. of the Tyne, taken 19th May, 1914, was recorded in the Report of last year, and it was also noted that other specimens had been found amongst herrings by local fish merchants. The fish was 23·2 cm. long, and a male apparently recovering after spawning.

In order to see if the scales of the pilchard had similar transparent rings to the winter rings of the scales of the herring, an examination was made of the scales taken from the side of the body from behind the operculum to a level with the posterior end of the anal fin The scale-covered portion of the body was divided into seven areas as follows:—*A*, from behind the operculum and covering one-third of the distance to the beginning of the dorsal fin; *B*, from *A* to immediately in front of the dorsal fin; *C*, the area below the dorsal fin; *D* and *E*, the anterior and posterior half respectively of the region between the end of the dorsal and beginning of the anal fin; *F* and *G*, the anterior two-thirds and posterior third of that part of the body above the anal fin. The body behind the end of the anal fin was void of scales.

Altogether 108 scales were examined, and in 84 of these six transparent rings were to be seen. The remaining 24 scales, from which it was impossible to determine exactly the number of transparent rings, came from that part of the body posterior to the beginning of the anal fin. Generally, the rings were distinct in their apical portion, but were more strongly marked at the anterior angles of the scales. Scales taken from areas *C* and *D*, that is, from below the beginning of the dorsal fin to halfway between the end of the dorsal and beginning of the anal fin, were found to have the transparent rings well marked in all cases. In scales from the anterior portion of the body, areas *A* and *B*, the first winter ring, although clearly marked at the sides, was often somewhat

indistinct in its apical portion, and the same may be said of those from the area immediately in front of the beginning of the anal fin.

By following the same method as employed in the case of the herring for determining the size of the fish at the formation of the winter rings, the figures given in Table I. were obtained, and the limits of variation are shown. It will be observed that the lowest average for the size at the formation of the first winter ring was obtained from area *D*, and that the sizes at the formation of the second, third, fourth and fifth winter rings gradually increase as the scales are taken nearer and nearer to the posterior end of the body. The sizes obtaining at the formation of the first winter ring may be influenced by the apical portion of the ring being somewhat indistinct in scales from the anterior and posterior portion of the body.

Through the kindness of Mr. D. C. Miller, of North Shields, it was possible to obtain samples of scales from eighteen pilchards, which were caught during the herring season of last year, and had been pickled and preserved more as curiosities than anything else. The length of these fish, the number of transparent rings, and the size at the formation of these rings will be found in Table II.

Our local waters are not visited by large numbers of pilchards, and the opportunity is not afforded of making intensive investigations with regard to this fish, which is doubtless a migrant into the North Sea after spawning in the Channel, or in exceptional years in the southern portion of the Flemish Bight. But it is more than probable that investigations carried out where material is plentiful would throw considerable light on the question of the growth of the pilchard and the age composition of the shoals which annually visit the southern waters of this country.

TABLE I.

Area of Body.	Size in cm. at Formation of Transparent Rings.											
	1		2		3		4		5		6	
A ...	10·4	1·1 0·6	18·9	0·6 0·4	21·5	0·2 0·2	22·1	0·2 —	22·6	0·1 —	23·0	— 0·1
B ...	11·3	0·8 0·6	18·8	0·2 0·3	21·4	0·4 0·2	22·1	0·2 0·1	22·6	0·1 0·2	22·9	0·1 —
C ...	10·5	0·6 0·6	18·9	0·3 0·5	21·6	0·2 0·2	22·3	0·1 0·2	22·7	0·1 0·1	23·0	
D ...	10·1	1·2 0·6	19·1	0·4 0·3	21·7	0·2 0·3	22·3	0·2 0·1	22·7	0·1 —	23·0	
E ...	10·2	0·2 0·3	19·4	0·3 0·1	21·8	0·2 0·1	22·4	0·1 0·1	22·7	0·1 —	23·0	
F ...	10·8	0·4 0·4	19·9	0·2 0·4	22·1	0·2 0·1	22·5	0·2 0·1	22·8	— 0·1	23·0	
G ...	11·1	0·2 0·3	20·1	0·4 0·2	22·3	0·1 0·1	22·6	0·1 —	22·8	0·1 —	23·0	0·1 —

TABLE II.

Length in cm.	Transparent Rings.	Size at Formation of Transparent Rings.										
		1	2	3	4	5	6	7	8	9	10	11
21·2	3	11·4	17·6	20·3	—	—	—	—	—	—	—	—
22·1	3	12·5	19·4	21·7	—	—	—	—	—	—	—	—
23·3	3	9·0	16·5	21·5	—	—	—	—	—	—	—	—
22·4	5	7·3	12·8	18·5	21·0	21·9	—	—	—	—	—	—
22·5	5	7·8	16·3	19·2	20·9	22·0	—	—	—	—	—	—
23·7	5	9·2	16·0	19·2	22·1	23·1	—	—	—	—	—	—
24·3	5	9·2	15·9	20·1	22·3	23·9	—	—	—	—	—	—
21·5	6	7·5	15·0	18·8	19·8	20·7	21·2	—	—	—	—	—
23·0	6	8·8	15·5	19·8	21·7	22·4	22·8	—	—	—	—	—
23·8	6	9·1	16·9	20·9	22·1	22·8	23·5	—	—	—	—	—
24·0	6	10·6	17·0	20·9	22·4	23·5	23·8	—	—	—	—	—
24·2	6	8·5	17·2	20·9	22·7	23·6	24·0	—	—	—	—	—
24·6	6	8·9	15·0	20·1	22·6	23·7	24·4	—	—	—	—	—
25·3	6	11·2	20·0	23·1	24·2	24·6	25·0	—	—	—	—	—
23·9	8	7·0	12·1	17·0	20·8	22·1	23·0	23·5	23·8	—	—	—
24·2	9	8·8	14·4	18·0	20·0	21·5	22·4	23·2	23·7	24·0	—	—
24·4	11	8·7	15·1	19·0	21·6	22·5	23·0	23·4	23·8	24·0	24·2	24·3
25·8	6+	8·7	14·0	19·2	23·1	24·1	24·6	(?)	—	—	—	—

FAUNISTIC NOTES.

By B. STORROW.

Eggs of the Gunnel (*Pholis gunnellus*, Linnæus).—Whilst searching amongst the rocks for eggs of shore fish on the 4th of March of this year, a cluster of eggs, about the size of a walnut, with two gunnels in close proximity, was found under a large piece of rock. The eggs and fish were in about an inch and a half of water on a sloping ledge of rock, the seaward side of which was from two to three inches above a pool some eighteen inches deep. One gunnel was coiled round the eggs, and facing it was the other about six inches away.

As no attempt was made to escape on the covering rock being removed some curiosity was aroused, and in order to see what would happen the eggs were lifted and placed about three inches from the tail of the fish which was coiled round them. This fish at once moved its head and shortly observing the eggs moved towards them and again coiled round them. The other fish did not move. The first fish was then gently pushed from the eggs to the edge of the rock until it was partly in the water. Although touched several times the creature made no attempt to escape, and it had to be pushed into the deeper water before any effort was made to swim away. Whilst this had been taking place, the other gunnel had moved along towards the eggs, a distance of about one foot, and coiled itself round them The eggs were then taken out of the coil and moved about two feet from the tail of the fish, which, after some slight movement of the head, found them again and coiled round them. The mass of eggs was then placed in a small bottle and some hatched out on the way to the Laboratory.

Some of the young lived until the 27th of March, when there was only a small quantity of the yolk and oil globule remaining. There was a large chromatophore on what remained of the yolk, and about twenty-eight forming a line below the yolk and to the anus. From the anus the chromatophores ran upwards and

forwards until reaching the base of the ventral fin, and then almost to the end of the tail.

Fin rays had begun to develop in the pectoral, dorsal and ventral fins.

Other two masses of the eggs of the gunnel were found under stones in the same locality, and only one fish was seen in each case. The moving of the stones disturbed the water, and made observations difficult.

Protula tubularia, Mont. A mass of tubes having a base of 8 inches by 5 inches and being about 5 inches in height, was brought ashore by one of the local fishing boats on 16th September, 1914, from 17 fathoms N.E. of Cullercoats. The creatures are now living in a large glass jar, and have made additions to the length of the tubes. Shortly after capture retraction into the tubes took place if the jar was approached in anything but a very cautious manner. Now the creatures are not so sensitive, and generally remain fully expanded until a slight tap is given to the jar, when retraction of the majority instantly takes place.

Nerilla antennata, O. Schmidt. Found 15th January, 1915, amongst Nemerteans brought in from the north side of Cullercoats Bay, obtained near high water mark, and from below stones resting on fine gravel and coarse sand. Unfortunately the specimen when being examined alive was destroyed by the slipping of the cover slip, but what notes were made from a dorsal examination are here given :—

Head.—Rounded with fringe of cilia. Tentacles three, articulated, median with eight articulations, two lateral evidently damaged and showed only three and five articulations. Palpi clavate and lateral with fringe of cilia distally and anteriorly. Eyes four, pale reddish purple, anterior pair wider apart than posterior, which were slightly behind palpi. The anterior border of the head changed somewhat and appeared less rounded as the creature progressed.

Body of nine bristle bearing segments, the first with a pair of articulated cirri of six and seven articulations respectively and

shorter than the median tentacle. Patches of cilia behind feet. Intestine without constrictions. Two articulated cirri of three and six articulations (obviously damaged) at end of body. Total length about 1 mm.

Foot with single cirrus, carrying capillary bristles, apparently projecting above and below the cirrus.

Aplysia punctata, Cuvier. Young specimens were obtained from the local rocks on 19th January, 1915. Older and larger individuals now occur (June), and are spawning. This is the first time these have been obtained since 1912, when the species was exceptionally abundant. Mr. Nathaniel Colgan, in the *Irish Naturalist* of Aug.-Sept., 1914, page 170, notes the occurrence in remarkable numbers of *A. punctata* in Irish waters between Shennicks Island and Skerries mainland in 1908, and a second abundance in 1913, a period of five years. From the growth made by small individuals kept in the tanks of the Laboratory and their spawning in June, coupled with a total disappearance from the district in the following year, it would appear that *A. punctata* lives only for one year, and after reproduction dies.

Pleurobranchus plumula (Montagu). Twelve specimens of about one centimetre in length were obtained under stones near low-water mark to the north side of Cullercoats Bay on the 1st of February, 1915.

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